# REPORT OF COPPER LOADING
to
# SAN DIEGO BAY, CALIFORNIA

Prepared For

Mr. Arthur Coe
California Regional Water Quality Control Board, San Diego Region
and the
San Diego Bay Interagency Water Quality Panel

December 6, 1996

Prepared By

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# 4.0 ESTIMATION OF ANNUAL COPPER LOAD FOR SAN DIEGO BAY

The annual copper load for San Diego Bay was estimated using available data and several conservative assumptions. The following subsections summarize the point and nonpoint source estimates, discuss the assumptions made to arrive at the estimates, and presents a simple tidal prism model of San Diego Bay.

## 4.1 SUMMARY OF POINT AND NONPOINT SOURCE ESTIMATES

The annual copper load for San Diego Bay is estimated to be 37,589 kg (82,818 pounds). This annual mass loading of copper is the equivalent of an average daily load of 103 kg (227 pounds). Table 4-1 summarizes copper loading from point and nonpoint sources. Figure 4-1 depicts the copper load contribution from each source in terms of mass (kg and pounds) and as a percentage of the total load. A review of Table 4-1 and Figure 4-1 indicates that input from antifouling hull paints (including in-water hull cleaning, passive leaching and ship and boat yard paint removal activities) followed by wet weather flows are by far the greatest contributors to the copper loading of the bay (90 percent). Contributions to the estimated annual copper load to San Diego Bay are:

- Antifouling hull paints (includes copper from leaching, hull cleaning, and ship and boat yards) 82.2 percent (30,896 kg)
- Wet and dry weather flows 11.2 percent (4,205 kg)
- Transfer of copper from sediment to water 6.0 percent (2,240 kg)
- Other identifiable sources include 0.48 percent (181 kg) from the SDG&E South Bay Power Plant, 0.06 percent (21 kg) from rainfall, and 0.11 percent (41 kg) from atmospheric deposition

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December 6, 1996

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**Report of Copper Loading to San Diego Bay, California For the San Diego Bay Interagency Water Quality Panel**

Dear Mr. Coe:

Enclosed is the above-referenced report prepared by PRC Environmental Management, Inc. (PRC). This report presents descriptions of the methods used, assumptions made, and work completed to (1) estimate the mass of copper released to water and sediment from anti-fouling hull paints, (2) estimate the mass transfer of copper between water and sediment, (3) summarize the copper loading to San Diego Bay from stormwater runoff and dry weather flows report by Woodward-Clyde Consultants (WCC), and (4) estimate the total annual waste load of copper to the bay. The data used in the analyses and the computations used to arrive at the estimations, as well as the WCC report in its entirety, are included as appendices to the report.

If you have any questions or comments, please call me at (619) 718-9676.

Sincerely,

Peter M. Stang, RG
Project Manager

Enclosures (8)

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| Dry Weather Source | Example |
|---|---|
| NPDES Permittees | Shipyards, dewatering facilities, power plants |
| Upstream Reservoirs | Sweetwater Reservoir, Otay Lakes, copper sulfate additive |
| Groundwater Base Flows | Upstream groundwater basins |
| Illegal Discharges | Dumping, improper plumbing, boatyard washing |
| Incidental Discharges | Car washing, irrigation return flow, fire fighting |

The largest potential source of dry weather copper in most urban areas is from NPDES permittees. However, in San Diego most of these discharges have been eliminated since 1964. The WCC estimates of copper contributions for wet and dry weather flows are as follows:

| Source | Low Range (kg) | High Range (kg) | Low Range (pounds) | High Range (pounds) |
|---|---|---|---|---|
| Wet-weather runoff<br>Total Copper<br>Dissolved Copper | 1,288<br>909 | 2,471<br>1,642 | 2,834<br>1,999 | 5,436<br>3,613 |
| Bayside Industrial Stormwater<br>Airport (Lindbergh Field)<br>Naval Facilities<br>Shipyards/Industrial | >0<br>>0<br>>0 | 379<br>39<br>43 | >0<br>>0<br>>0 | 833<br>85<br>96 |
| Reservoirs (copper sulfate)<br>Sweetwater<br>Otay | 410<br>0 | 1,273<br>0 | 902<br>0 | 2,800<br>0 |
| Otay River<br>(copper background) | Amount likely to be extremely small and not significant in total copper loading. | | | |
| Illicit connections<br>Illegal disposal | Copper load not possible to estimate with existing data. These are definitely a source of copper greater than zero; there are no published data or concentration and flow rate information to develop an estimate. | | | |
| Total | 1,698 | 4,205 | 3,736 | 9,250 |

For the purposes of this study, the most conservative (high range) values presented in the WCC report were used. The WCC report includes comments regarding most of the estimated copper load values. The results of the study of wet and dry weather flows by WCC yield an estimated load of copper to San Diego Bay of 4,205 kg per year.

# CONTENTS

## 3.4 NONPOINT SOURCE COPPER RELEASES

WCC submitted a report (Appendix A) analyzing the contribution of copper from stormwater runoff and dry weather periods. According to the report, annual copper loading from storm water flows were estimated using spreadsheets in a watershed-based approach. Watersheds draining into San Diego Bay were defined by area, land use, impervious cover, theoretical and sampled runoff copper concentrations, and average annual precipitation. This information was used to estimate wet-weather copper loading. Informational sources used for the study included:

| Source | Data Provided |
| --- | --- |
| Federal Highway Administration 1990 | Event mean concentrations for transportation corridors |
| City of San Diego and Co-Permittee National Pollutant Discharge Elimination System (NPDES) Stormwater Monitoring Program 1993-1996 | Event mean concentrations for urban land uses |
| National Urban Runoff Program | Event mean concentrations for parks and open land |
| Santa Clara Valley and Bay Area Stormwater Monitoring Programs 1987-1994, 1996 | Event mean concentrations for parks and open land |
| County of San Diego Hydrology Manual 1985 | Average annual precipitation by watershed |
| San Diego Association of Governments 1990 GIS Generalized Land Use | Percent impervious cover, watershed area |

Contributions of copper during dry weather periods potentially include discharges from NPDES permittees, releases from upstream reservoirs, groundwater base flows, illegal discharges, and incidental flows. Some examples of these types of flows are as follows:

## FIGURES



## TABLES

(in water) or sorbed (in sediment). Therefore, a simple estimate of the concentration in water and sediment using equilibrium partitioning is not applicable. Because copper is present as particulate matter (paint chips, copper slag debris, copper ore debris, and naturally occurring copper containing minerals) equilibrium partitioning cannot be used to estimate the flux (adsorption or desorption) of copper between sediment and water.

However, the Navy's benthic flux chamber attempts to measure concentrations of constituents at the sediment-water column interface by creating a small control volume which is monitored over time. A knife-edge enclosure is used to seal the control volume against the bay floor, oxygen content of the control volume is then controlled to the greatest extent possible. An onboard data logger collects data from several sensors mounted in a flow-through loop including pH, salinity, temperature, and oxygen content. Water samples are collected over time and analysis of the water samples provides measurement of the change in concentration of chemicals of interest, including copper. The typical deployment period is less than 72 hours and sample analysis from the device can be used as an indication of fluxes over a larger benthic surface area.

### 3.3.2 Spatial Variability

Figure 3-1 shows a compilation of sediment data collected during one previous study (California Department of Fish and Game 1995). These data indicate that sediment copper concentrations are highly variable, except for a number of "hot spots" where there have been consistent, long term, point discharges of copper. Locally high sediment copper concentrations are attributable to the presence of storm drain outfalls, hull cleaning, and other point discharges such as the PACO Ore terminal, where copper ore was spilled into San Diego Bay for a number of years (Valkirs and others 1994).

The whole bay median sediment copper concentration in one study was found to be 88 mg/kg based on the BPTC data (California Department of Fish and Game 1995) and ranged from 6.0 to 660 mg/kg.

Fluxes for certain metals from the 1993 and 1995 San Diego Bay deployments of the Navy's benthic flux sampling device show some consistent relationships for certain metals. Manganese (Mn), zinc (Zn), nickel (Ni), and cadmium (Cd), for example, show fairly consistent fluxes out of the sediments. However, the remaining metals, including copper, show variable behavior with fluxes both into and out

# EXECUTIVE SUMMARY

The San Diego Bay Interagency Water Quality Panel (SDBIWQP) asked PRC Environmental Management, Inc. (PRC) to: (a) estimate the mass of copper transferred from ship and boat antifouling paints to San Diego Bay; (b) estimate the mass of copper transferred between sediments and water in San Diego Bay; (c) estimate the annual load of copper to San Diego Bay; and (d) prepare this report describing the above research. SDBIWQP also separately asked Woodward-Clyde Consultants (WCC) to estimate the mass of copper discharged to San Diego Bay as a result of storm events and dry weather periods. This estimate and the associated WCC report are summarized in this document and presented as Appendix A.

Copper currently enters San Diego Bay water and sediment from several distinct sources. Copper-containing antifouling ship and boat hull paints comprise the single largest source. Copper is also discharged to the bay during stormwater flows and dry weather periods. Copper is apparently accidently discharged from ship and boat yards through the loss of removed copper antifouling paint and some paint removal blasting media. Another source is the San Diego Gas and Electric (SDG&E) South Bay Power Plant. Although the transfer of copper between sediment and water in San Diego Bay may be at or near equilibrium throughout the bay, we have conservatively estimated that the bay sediments exhibit a net release of copper from sediment to water.

With the implementation of best management practices at industrial sites within the San Diego Bay watershed (including shipyards and boatyards adjacent to the bay), copper loading from these sources has likely been reduced in recent years. Copper loading from the passive leaching of antifouling paints is directly related to the rate of copper release from applied paints and the total wetted hull surface area of vessels coated with copper-containing antifouling paints. Copper loading from in-water hull cleaning activities in San Diego Bay is dependent on the frequency of cleaning, the age of the hull paint, and variations in the methods used to clean the vessels.

The total annual copper load to San Diego Bay is estimated to be 37,589 kilograms (kg) (82,818 pounds). Contributions to the estimated annual load include: 28,804 kg (63,484 pounds) from copper-containing antifouling hull paints, including 12,747 kg (28,094 pounds) of copper released during in-water hull cleaning and 16,057 kg (35,390 pounds) of copper released by passive leaching; 2,092 kg

The average of the 24-hour interval APCD copper concentrations from 1990 to 1995 is $6.32 \times 10^{-11}$ $kg/m^3$ which can be used for C(t). The surface area of the bay is $4.15 \times 10^7$ $m^2$, the value for S. An overall year around average of 2 micrometers ($\mu m$) was chosen by WCC (WCC 1996) for particle size, and is used here for consistency between the two reports. The average annual wind speed measured at Lindbergh Field is 3.1 m/s. Using a "smooth sea" surface roughness factor of 0.02, a friction velocities table referenced by WCC (WCC 1996) shows that the friction velocity for this particle size is 13.3 m/s. The closest plot of particle diameter versus deposition velocity is for 10 cm/s which corresponds to $v_d(t) = 5 \times 10^{-4}$ m/s. Solving for deposition into the bay per year:

$$F(\text{year}) = (6.32 \times 10^{-11}\ kg/m^3)(5 \times 10^{-4}\ m/s)(4.15 \times 10^7\ m^2)(3.1536 \times 10^7\ s/\text{year})$$
$$= 41\ \text{kg copper per year}$$

## 3.3 TRANSFER OF COPPER BETWEEN BAY SEDIMENTS AND WATER

An assessment of long-term trends in copper loading in San Diego Bay requires the study of bay sediments and interaction with the overlying water column. Sediments, water chemistry, presence of organic matter and, to a lesser extent, tidal currents all play important roles in San Diego Bay responses to copper loading.

### 3.3.1 Historical Data

Copper in San Diego Bay sediments and water has been the focus of much past study. These studies have been conducted by NCCOSC RDT&E Division, Center for Coastal Studies, Scripps Institute of Oceanography, State of California Department of Fish and Game, and by graduate students at various universities. The most important of these studies in estimating the transfer of copper between sediment and water in San Diego Bay include data collected through use of a benthic (ocean floor) flux chamber developed by the Navy that measures in situ flux of contaminants between sediment and water. The data show little change in sediment copper concentrations during an interval of a decade at certain sites (Valkirs and others 1994). These results are discussed in the following subsections.

Simple equilibrium phase partitioning to estimate the concentration of copper in sediment based on the concentration in water (or vice versa) cannot be performed because copper is not exclusively dissolved

## FORWARD

ı Diego Bay is the most southerly deep water port on the Pacific coast of the United States. Many neficial uses exist in the Bay, including commercial, industrial, recreational, and wildlife uses. The n Diego Interagency Water Quality Panel (Bay Panel) has identified chemical constituents of concern the beneficial uses of the Bay. The highest priority constituents which may be controlled through ductions at the source were copper and polycyclic aromatic hydrocarbons (PAHs). Portions of the ... are also identified under Clean Water Act Section 303 (d) as impaired from copper. The magnitude of historic and ongoing discharges of copper and PAH had not been determined.

The purpose of this project is to estimate loading of copper and PAH to the Bay from point and nonpoint sources. To accomplish this objective, the project utilized a wide range of available data sources which varies in both quantity and quality of information. In cases where little or no direct information were available the project utilized waste load modeling and data from other representative watersheds. Using the best available measurements and estimates the magnitude of sources are ranked and future data needs are identified. A mass balance approach is used which considers sources and sinks of the constituents in the bay, as well as, a water balance.

This information will be used to evaluate priorities to determine where actions may be most effective. The information is a major resource to be used by the Bay Panel in the development of a comprehensive management plan for San Diego Bay. The information will also assist the Regional Water Quality Control Board in the development of Total Maximum Daily Loads (TMDL) as required by Section 303 (d). Total Maximum Daily Loads are the total amount of a pollutant which is allowed to enter the Bay. This load is allocated to point and nonpoint sources with a margin of safety to account for uncertainty in the information.

This project is under the direction of the San Diego Interagency Water Quality Panel, a local organization of 31 public, private, and non-profit member organizations. The Panel, which was authorized under legislation adopted by the California Legislature in 1992, is directing this project through its Total Maximum Daily Load Review Committee. Funding for this project was provided by the U.S. Environmental Protection Agency and the California State Water Resources Control Board under Section 205(j) of the Clean Water Act.

### 3.2.5 Other Identifiable Sources

SDG&E has reported copper released to the bay in cooling water from the South Bay Power Plant. Based on SDG&E calculations, the amount of copper released from all condenser and salt water heat exchanger tubes is estimated to be between 136 and 181 kg per year, or approximately 0.37 to 0.50 kg per day (Peterson 1996).

The copper contained in rainfall falling onto the surface of the bay each year is an identifiable loading source. The San Diego office of the National Weather Service (NWS) was contacted regarding average yearly rainfall in San Diego. NWS indicated that the San Diego region receives an average 9.90 inches (0.251 m) of rainfall annually. NWS staff were unaware of any data that have ever been collected regarding chemical composition of the rain that falls in the San Diego region. An estimate of the amount of copper contributed by rainfall is still possible, however, by assuming that the copper concentration in rain is equivalent to the ambient sea water concentration of 2.0 $\mu$g/L ($2\times10^{-9}$ kg/L). The mass of copper contributed each year to the bay from rain falling directly onto the surface can then be calculated by multiplying the surface area of the bay ($4.15\times10^{7}$ $m^2$) by the annual rainfall (0.251 m) and the concentration of copper in the rain ($2\times10^{-6}$ kg/$m^3$). The result is 21 kg/year.

Air deposition into San Diego Bay is also an identifiable source of copper loading. The County of San Diego Air Pollution Control District (APCD) has collected data on air pollutants, including copper, from its monitoring stations in El Cajon and Chula Vista since 1990. Because Chula Vista is located adjacent to the bay, WCC (WCC 1996) is using APCD polynuclear aromatic hydrocarbon (PAH) data from the Chula Vista monitoring station to estimate air deposition of PAHs into the bay for the SDBIWQP. Their approach is followed in this study for air deposition of copper to maintain consistency between the reports for SDBIWQP use.

The following relationship was used by WCC to estimate deposition into the bay per unit time, F(t):

$$F(t) = C(t)v_d(t)S$$

where $C(t)$ = ambient air concentration (kg/$m^3$)

$v_d(t)$ = deposition velocity (m/second[s])

$S$ = total surface area for deposition ($m^2$)

ds) discharged from ship and boat yards from copper paint residue and copper containing sting media; 2,932 kg (6,450 pounds) from stormwater flows, 1,273 kg (2,800 pounds) oirs, 2,240 kg (4,936 pounds) from transfer of copper from sediment to water; and 243 kg is) from other sources.

nmends that additional study be conducted regarding several of the parameters needed to the development of total maximum daily load (TMDL) criteria for San Diego Bay. These idations include: (1) identification and assessment of additional sources of copper; (2) ation of release rates of copper from private and commercial vessel hulls; (3) additional data n on copper transfer between sediment and water; (4) application of link node or other types of uch as the model used to describe copper loading and fate in San Francisco Bay; (5) collection egarding copper concentrations in the water column throughout the bay including both source kground areas; and (6) collection of offshore copper concentrations in coastal Southern ia ocean waters to estimate background copper concentration since all models will be extremely e to the ocean background copper concentration input.

The annual estimate of 1,418 kg of copper for the four ship yards seems reasonable based on the 18,000,000 to 27,000,000 kg (20,000 to 30,000 tons) of spent abrasive being generated annually by hull blasting operations (Austin 1996). Unspent copper slag contains approximately 2,000 mg/kg of copper (Austin 1996). It is used to blast steel hulled vessels in the ship yards. Spent copper slag can contain in excess of 3,000 mg/kg of copper. At 3,000 milligrams ($3x10^{-3}$ kg) of copper per kg of waste, the estimated 1,419 kg of copper lost from the ship yards represents a loss of 0.3 percent of the spent abrasive used.

Commercial Basin and South Bay Boat Yards

The sediments of Commercial Basin exhibit elevated concentrations of copper. The average copper concentration in four samples reported in a summary of Bay Protection Toxic Clean-up (BPTC) data for Region 9 (California Department of Fish and Game 1995) is 297 mg/kg. The background copper concentration for the basin was assumed to be equivalent to the average of the ship yard sediment background which is 126 mg/kg copper. The area of Commercial Basin can be approximated as a rectangle with 700 m sides (north to south) and 520 m sides (east to west). The estimated impacted sediment area is 364,000 $m^2$. Assuming that the boat yards located in Commercial Basin are the only contributors to the copper in the sediments and using the same parameters as for ship yards, the estimated copper load from the four boat yards is 539 kg per year or 135 kg per boatyard per year. This estimate is likely conservative because it assumes all the sediment is impacted at the same level as the BPTC sampling station located near a boat yard, and it does not account for accumulation of copper in sediment from passive leaching of copper or from in-water hull cleaning activities.

No data were available for the South Bay Boat Yard at the time of this report. For the purposes of the load estimation it is conservatively assumed that the boat yard contributes 135 kg annually, an amount of copper equal to 25 percent of the load from the four yards in Commercial Basin. The total estimated annual copper loading to San Diego Bay from the five boat yards is 674 kg. The total estimated annual copper load on San Diego Bay from all boat and ship yards is 2,092 kg.

## 1.0 INTRODUCTION

The San Diego Bay Interagency Water Quality Panel (SDBIWQP) asked PRC Environmental Management, Inc. (PRC) to: (a) estimate the mass of copper transferred from ship and boat antifouling paints to San Diego Bay; (b) estimate the mass of copper transferred between sediments and water in San Diego Bay; (c) estimate the annual load of copper on San Diego Bay; and (d) prepare this report describing the above research. SDBIWQP also separately asked Woodward-Clyde Consultants (WCC) to estimate the mass of copper discharged to San Diego Bay as a result of storm events and dry weather periods. This estimate and the associated WCC report are summarized in this document and presented as Appendix A.

Copper currently enters San Diego Bay water and sediment from several distinct sources. Copper-containing antifouling ship and boat hull paints comprise the single largest source. Copper is also discharged to the bay following storm events and during dry weather periods. Copper is apparently accidently discharged from ship and boat yards through the loss of removed copper antifouling paint and some paint removal blasting media. Another source is the San Diego Gas and Electric (SDG&E) South Bay Power Plant. Although the transfer of copper between sediment and water in San Diego Bay may be at or near equilibrium throughout the bay, we have conservatively estimated that the bay sediments exhibit a net release of copper from sediment to water.

Historically, prior to settlement and substantial industrialization of San Diego, copper loading to San Diego Bay occurred naturally through sediment deposition from stormwater runoff. This deposition could be viewed simply as the transfer of earths crustal material from land to sea. In the Twentieth Century, San Diego Bay development had reduced the natural sediment load to the bay by diverting the San Diego River and damming the Sweetwater and Otay Rivers. Current activities that provide copper loading to the bay include industrial discharges, the use of copper-containing ship and boat hull antifouling paints, hull cleaning, boat and ship yards, and urban stormwater runoff.

Comparing the crustal abundance of copper on a geologic scale with the sediment concentrations in San Diego Bay demonstrates the magnitude of the impact of development activities on the bay. The whole earth average background crustal copper concentration is 50 milligrams per kilogram (mg/kg); in seawater, the average global concentration is 0.5 micrograms per liter (µg/L) (Krauskopf 1979).

background sediment concentration is 288 mg/kg copper. The estimated copper load is 222 kg per year.

## Southwest Marine

The area of elevated sediment copper concentration at the Southwest Marine ship yard was estimated by inscribing a rectangle on a map of the ship yard from Pier 1 to Pier 5 (approximately 317 m in length north to south) and out into the bay 213 m (east to west). The average sediment copper concentration is 794 mg/kg. The background sediment concentration is 190 mg/kg copper. The estimated area is 67,648 $m^2$. The estimated copper load is 354 kg per year.

## NASSCO

The area of elevated sediment copper concentration at the NASSCO ship yard was estimated by inscribing a rectangle on a map of the ship yard from Berth 11 to Berth 2 approximately 396 m in length (north to south) and out into the bay 213 m (east to west) and adding a right triangular area inscribed from the south edge of Berth 2 to a shoreline point opposite the most southerly sampling location, NSS-17. The base of the right triangle (north to south) measures approximately 386 m with a height (east to west) of 396.2 m. The estimated area of sediment impact is 152,933 $m^2$. The average sediment copper concentration is 565 mg/kg. The background sediment concentration is 23 mg/kg copper. The estimated area is 152,933 $m^2$. The estimated copper load is 718 kg per year.

The estimated total annual copper loading to San Diego Bay from the four ship yards is 1,418 kg. Appendix B contains the calculations used to arrive at the loading estimate. The total annual load is most likely a conservative estimate. The approximation does not allow for copper released by passive leaching from ship hull paints. It also assumes that no mixing of sediments occurs. The data more likely represents the mean copper loading since the last dredging operations because sediment mixing and homogenization will average the sediment copper concentration. If best management practices have reduced the copper load in recent years, then these annual ship yard loads have been overestimated and are lower.

However, VanderWeele has documented a concentration of 2.0 $\mu$g/L for southern California coastal ocean water at a sampling station off La Jolla, California (VanderWeele 1996). Considering that the bay has received a historical loading of copper through sediment transport and anthropogenic copper sources, 50 mg/kg is relatively close to the bay-wide median sediment copper concentration of 88 mg/kg and within one order of magnitude of the highest recorded sediment copper concentration found during an August 4, 1993 field survey of 660 mg/kg (California Department of Fish and Game 1995). This concentration of 660 mg/kg is exclusive of elevated copper concentrations previously identified and remediated by source removal at the P[illegible] Terminal, the former location of a copper ore loading facility.

This report estimates of the annual copper load to San Diego Bay. Section 1.0 is an introduction to the subject of the report. Section 2.0 describes the work performed to estimate the copper loading. Section 3.0 describes the methods and assumptions used to estimate the contribution of copper from point sources, bay sediments, and nonpoint sources. Section 4.0 contains the estimation of annual copper loading to San Diego Bay from all sources described in Section 3.0 and a listing of principal assumptions. Section 5.0 contains recommendations regarding further areas of study. A list of references follows in Section 6.0.

This project is under the direction of the Total Daily Maximum Load Review Committee of the SDBIWQP. The SDBIWQP is comprised of 31 public, private, and nonprofit member organizations, and was authorized by the California Legislature in 1992. Funding for this project was provided by the U.S. Environmental Protection agency and the California State Water Resources Control Board under Section 205(j) of the Clean Water Act.

- Area of each yard impacted by copper was estimated as described below
- Sediment thickness represented by bottom samples was 2 cm
- Dry sediment density of 1.3 g/cc (grams per cubic cm) was used
- Dry mass of copper was annualized by dividing it by 3 years, the approximate number of years represented in a 2 cm thick bottom sediment sample based on a sedimentation rate of approximately 7 mm/yr (millimeters per year) (Stang 1985)

Sediment samples have also been collected and analyzed for copper adjacent to each support pier of the San Diego-Coronado Bay Bridge by a consulting firm working for California Department of Transportation (CalTrans) (A.E. Schmidt 1996). The distance from the Continental Maritime ship yard shoreline to the point that bottom sediments begin to exhibit elevated concentrations of copper was estimated using the CalTrans data. Sediment samples were collected adjacent to the piers from west to east along the bridge as it approaches the Continental Maritime ship yard. Elevated concentrations of copper were present in bottom sediments starting near bridge Pier 21, approximately 213 m from shore. The following subsections describe the procedure followed to estimate the surface area of each ship yard and their estimated copper loading to San Diego Bay.

## Continental Maritime

The are of elevated sediment copper concentration at the Continental Maritime ship yard was estimated by inscribing a rectangle on a map of the ship yard from Pier 1 to Pier 7 (approximately 310 m in length north to south) and out into the bay 213 m (east to west). The estimated area is 66,346 $m^2$ (square meters). The average sediment copper concentration is 219 mg/kg. The background concentration is 3.1 mg/kg copper. Applying the parameters described above, the estimated copper load is 124 kilograms (kg) per year.

## Campbell

The area of elevated sediment copper concentration at the Campbell ship yard was estimated by inscribing a rectangle on a map of the ship yard from Pier 0 to a shoreline point opposite Pier 5 (approximately 231.7 m in length north to south) and out into the bay 213 m (east to west). The estimated area is 49,445 $m^2$. The average sediment copper concentration is 807 mg/kg. The

## 2.0 WORK PERFORMED

PRC used a variety of resources to assemble this report. A determination of the mass of copper released to water and sediment in San Diego Bay from antifouling hull paints required both a review of literature on the subject and contact with Port of San Diego and U.S. Navy officials. PRC conducted a literature review to estimate the baywide mass transfer of copper between water and sediment. Literature sources reviewed regarding transfer of copper between sediments and water included the Naval Command Control, and Ocean Surveillance Center (NCCOSC), Research, Development, Test and Evaluation (RDT&E) Division and the State of California Department of Fish and Game. WCC estimated the copper loading to San Diego Bay from stormwater runoff and dry weather periods using a watershed-based approach supported by data from several sources including the National Urban Runoff Program and the San Diego Association of Governments (SANDAG) 1990 Geographic Information Systems (GIS) Generalized Land Use Database. The total annual load of copper to San Diego Bay was then calculated using copper mass loading figures arrived at through the above approaches. The total annual copper load determination included the contribution to the bay from the SDG&E South Bay Power Plant.

PRC then assembled the group of literature citations, assumptions, calculations, estimates, and supporting text into standard report format for submittal to the California Regional Water Quality Control Board, San Diego Region (RWQCB) and the SDBIWQP. Spreadsheet-style tables and figures have been used, where appropriate, to illustrate parameters affecting copper load determinations. The use of tables and figures was designed to make possible the review of copper loading totals calculated by PRC and WCC, prior to detailed review of the supporting text.

Many of the sources from which analytical data were obtained for this study do not specify whether the laboratory results they report represent total or dissolved copper concentrations. This leads to some degree of uncertainty and increases the number of assumptions necessary to generate the estimates of copper loading to the Bay. In addition, several different laboratories, each following their own internal quality assurance and quality control (QA/QC) program, provided the analytical data.

### 3.2.4 Ship and Boat Yard Operations

Copper containing debris is generated in ship and boat yards during copper paint removal prior to hull maintenance and repainting activities. Additionally, some paint removal methods utilize copper-containing blasting media. Paint removal can be performed by hand sanding, mechanical sanding, or blasting using water (hydroblasting), plastics, crushed nut shells, or copper slag (the aluminum and silica residue generated during copper ore smelting that contains approximately 2,000 mg/kg copper prior to use as a blasting media). Copper slag is generally used only on steel-hulled vessels; fiberglass and wooden hulls are damaged by its use. Actual quantitative data for releases of particulate copper from ship and boat yard operations into San Diego Bay are not available. These releases are accidental, unauthorized, and unmonitored. As such they are not typically reported to the responsible environmental agencies or included as part of industry permits. Information on the number of private vessel repair/painting facilities and approximate number of vessels repaired/painted each year is contained in references (Conway and Locke 1994, and McPherson and Peters 1995). The amount of copper containing antifouling paints applied to 7,600 pleasure craft in 1994 was estimated to be 22,000 liters (Valkirs and others 1994).

Four ship yards and five boat yards are located on San Diego Bay (Austin 1996). The ship yards collect and analyze sediment samples twice each year as a condition of their National Pollutant Discharge and Elimination System (NPDES) permits. The samples are collected from several fixed locations at each yard including at least one storm drain outfall. The samples are analyzed for a variety of pollutants including copper. The data are submitted to the RWQCB by each ship yard. The most recent sediment sample copper analysis results for the National Steel and Shipbuilding Company (NASSCO), Continental Maritime, Campbell Marine, and Southwest Marine ship yards were made available for this study by the RWQCB (Ecosytems 1996). The sediment samples were generally collected from the upper 2 centimeters (cm). The following parameters were used to estimate the mass of copper released from each ship yard based on the dry weight sediment copper analysis data (Ecosystems 1996) provided to PRC by the RWQCB:

- Average of all most recent sediment copper analysis results considered to be above background (sediment analysis results from storm drain locations were assumed to be background) concentration at each ship yard of the bay) are over represented as 9 out of 74, or approximately 12 percent, of the sample analysis results are used in the background calculation. These enclosed basins typically have elevated copper concentrations relative to the rest of the Bay due to the density of vessels coated with copper containing antifouling paints, shallower water, and restricted circulation.

## 3.2 POINT SOURCE COPPER RELEASES

This subsection describes methods used and assumptions made to arrive at a copper loading estimate to San Diego Bay from point sources including in-water hull cleaning, leaching from antifouling hull paints, and releases of removed paint and copper containing blasting media from ship and boat yard operations. The subsection ends with a discussion of other significant point and nonpoint release sources. Copper is present in antifouling hull paints because of its biocidal properties, which inhibit the attachment and growth of marine organisms. Antifouling paints generally contain copper in the forms of cupric resinate, cupric oxide, and cuprous oxide (Sax and Lewis 1987).

### 3.2.1 In-water Hull Cleaning—U.S. Navy Vessels

U.S. Navy hull cleaning is done by divers using mechanical brush machines. Valkirs and others (1994) studied the copper concentrations in bay water at various depths and distances adjacent to six U.S. Navy vessels before, during, and after hull brushing operations in 1991, 1992, and 1993. The position-relative-to-hull of samples containing maximum observed copper concentrations varied, but tended to occur approximately 3 meters from the vessel hulls during brushing. Valkirs and others (1994) attributes the variation to the fixed-point sampling performed which gave only an approximation of the water column copper concentrations for each plume volume studied.

In-water hull cleaning copper release for U.S. Navy vessels was estimated based on actual dissolved copper plume concentration and radius information contained in Valkirs and others (1994) that was collected during the six in-water hull cleaning operations. The maximum reported dissolved copper plume concentration (27 $\mu$g/L) was corrected from dissolved to total copper (135 $\mu$g/L) minus an ambient bay water copper concentration of 3.7 $\mu$g/L. The correction from dissolved to total copper concentration was possible because the report describes the method by which the plume samples were filtered and reports that a maximum of 80 percent of the particulate copper was removed from samples

TABLE 3-2

## COPPER LOADING TO SAN DIEGO BAY
## ESTIMATE OF ANNUAL DISCHARGE OF COPPER FROM PASSIVE LEACHING OF ANTIFOULING HULL PAINTS

| Vessel Type | Number of Vessels | Average Wetted Hull Surface Area per Vessel ($m^2$) | Total Wetted Hull Surface Area ($m^2$) | Fraction of Vessels With Copper AF Paint | San Diego Bay Residence Time (days per year) | Mass of Copper Discharged ($ug/cm^2$-day) | Annual Load per Vessel Type (kg per year) |
|---|---|---|---|---|---|---|---|
| US Navy Carriers | 2 | 14,818 | 29,636 | 1.00 | 122 | 10 | 362 |
| US Navy Submarines | 8 | 2,323 | 18,584 | 1.00 | 183 | 10 | 340 |
| US Navy Surface | 72 | 3,459 | 249,047 | 1.00 | 244 | 10 | 6,077 |
| US Navy Tugs and Other | 80 | 46 | 3,716 | 0.95 | 360 | 10 | 127 |
| | | | | | | US Navy Total | **6,906** |
| Pleasure/Small Commercial | 7,165 | 29 | 204,203 | 0.95 | 360 | 10 | 6,984 |
| Cruise and Passenger | 14 | 3,459 | 48,426 | 1.00 | 2 | 10 | 10 |
| Cargo | 148 | 9,121 | 1,349,863 | 1.00 | 3 | 10 | 405 |
| Barges | 25 | 334 | 8,350 | 1.00 | 3 | 10 | 3 |
| Tug Boats | 19 | 334 | 6,346 | 1.00 | 360 | 10 | 228 |
| Marine Construction | 10 | 334 | 3,340 | 1.00 | 244 | 10 | 81 |
| Miscellaneous and Visiting | 290 | 4,967 | 1,440,441 | 1.00 | 10 | 10 | 1,440 |
| | | | | | | Other Vessels Total | **9,151** |
| | | | | | | Total Annual Copper Discharged from Hull Paints (kg) | **16,057** |

Notes:

| | |
|---|---|
| AF | Antifouling |
| kg | Kilograms |
| ug | Micrograms |
| $cm^2$ | Square centimeters |
| $m^2$ | Square meters |

of the bay) are over represented as 9 out of 74, or approximately 12 percent, of the sample analysis results are used in the background calculation. These enclosed basins typically have elevated copper concentrations relative to the rest of the Bay due to the density of vessels coated with copper containing antifouling paints, shallower water, and restricted circulation.

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In-water hull cleaning copper release for U.S. Navy vessels was estimated based on actual dissolved copper plume concentration and radius information contained in Valkirs and others (1994) that was collected during the six in-water hull cleaning operations. The maximum reported dissolved copper plume concentration (27 $\mu g/L$) was corrected from dissolved to total copper (135 $\mu g/L$) minus an ambient bay water copper concentration of 3.7 $\mu g/L$. The correction from dissolved to total copper concentration was possible because the report describes the method by which the plume samples were filtered and reports that a maximum of 80 percent of the particulate copper was removed from samples

### 3.2.3 Antifouling Hull Paints

10 μg /cm²/day

Copper is released by passive leaching from copper containing antifouling paints. Copper loading to San Diego Bay by passive leaching is related to the release rate of copper from the paint and the total wetted hull surface area of vessels painted with copper antifouling coatings. Wetted hull areas for the two carriers homeported in San Diego as well as other U.S. Navy vessels in Table 3-2 were obtained from the Navy (Navy 1995). The total number of homeported surface ships is given (Navy 1995) as 72 with underwater hull surface area of 2,425,160 $ft^2$. It is assumed that the U.S. Navy carriers are in port about 122 days (1/3) of the year, submarines 183 days (1/2) of the year, surface vessels about 244 days (2/3) of the year, and tugs and other miscellaneous vessels about 360 days of the year. The San Diego Bay residence time estimates for non-Navy vessels in Table 3-2 are based on discussions with Mr. Libuda (360 days per year for pleasure craft, 3 to 5 days per visit per year in the case of commercial vessels). The non-Navy vessel wetted hull areas are consistent with previous estimates (Grouvhoug and others 1987).

Through passive leaching, copper hull paints release approximately 10 micrograms of copper per square centimeter of wetted hull per day ($\mu g/cm^2/day$) (Valkirs and others 1994). A wide range of values for the copper release rate is possible, since it decreases as antifouling hull paint ages; following hull cleaning, the release rate may increase (Stang 1991). In general, Navy and large commercial vessels are painted much less often than pleasure craft and so have older hull paint likely leaching copper below the 10 $\mu g/cm^2/day$ rate given by Valkirs and others (1994). Pleasure craft hulls are cleaned more often than large vessels and are painted on the average every 2 years (Conway and Locke 1994). They would therefore be expected to leach copper at higher rates than larger vessels. For this study, the 10 $\mu g/cm^2/day$ release rate has been used to represent the release rate for copper antifouling hull paints and representative of the median leach rate for the many vessels with different ages of paint berthed in San Diego Bay. The Navy has documented copper release rates (Stang 1991; Valkirs and others 1994) for several ships. These release rates range from 4 to 8 $\mu g/cm^2/day$. The estimate of 10 $\mu g/cm^2/day$ for the Navy is, therefore, a conservative estimate. No passive copper release rate data for private and commercial vessels are known to exist for San Diego Bay. Use of the 10 $\mu g/cm^2/day$ estimate for the non-Navy vessels represents one of the major uncertainties of this study. Table 3-2 contains estimates of annual copper releases from passive leaching of hull paints. The total annual load to San Diego Bay of copper leaching from antifouling hull paints is given in Table 3-2 as 16,057 kg.

prior to analysis for dissolved copper. No specific total copper concentrations were reported by Valkirs and others (1994). Therefore, this provides a conservative worst estimate, assuming that all 74 (29 surface vessels, 1 carrier, ~~4~~ 5 submarines, and 40 miscellaneous) of the estimated U.S. Navy vessels cleaned per year would release copper at the maximum concentration found by Valkirs and others (1994).

U.S. Navy copper releases from in-water hull cleaning are separated in Table 3-1 into carriers, submarines, surface, and tugs and miscellaneous vessels. Based on conversations with the Navy, approximately 29 surface vessels undergo hull cleaning each year. This represents 40 percent (29 out of 72) of the surface vessels. Additionally, 50 percent (1 out of 2) of the carriers, 50 percent (~~4~~ 5 out of ~~8~~ 10) of the submarines, and 50 percent (40 out of 80) of the tugs and other miscellaneous Navy vessels are estimated to undergo hull cleaning each year. The copper release estimates are presented in Table 3-1. The other miscellaneous vessels include barges, yard oilers, skiffs, and various small craft used by the Navy. Approximately 95 percent are assumed to be of steel, wood, or fiberglass hull construction, the rest are assumed to be aluminum hulled and not coated with copper paints. Aluminum hulled vessels are not painted with copper containing antifouling paints due to rapid hull corrosion problems associated with the use of copper paint on aluminum hulls.

The horizontal distances of plumes are based on data in Valkirs and others (1994) and the vertical distance (depth) (12 m) is based on an average depth of 40 feet in Navy docking and berthing areas. The number of homeported ships (not including submarines, tugs, and miscellaneous) is given as 72 in "Volume 1, Final Environmental Impact Statement, The Development of Facilities in San Diego/Coronado to Support the Homeporting of One NIMITZ Class Aircraft Carrier" (Navy 1995). The estimate of annual copper loading to San Diego Bay from in-water hull cleaning of U.S. Navy vessels is given in Table 3-1 as 230 kilograms (kg).

The calculation for U.S. Navy surface vessels is:

| | |
|---|---|
| Hull Cleanings: | 29 per year |
| Average Length and Width: | 122 m by 15.2 m (each vessel) |
| Hull Cleaning Plume Volume: | (6 m + 122 m + 6 m)(6 m + 15.2 m + 6 m)(12 m in depth) |
| | = 43,738 $m^3$ (each cleaning) |

dissolved copper. For the purposes of this estimate, it is assumed that total copper analysis was performed.

Assuming that the vessel displaced 15 tons of seawater, the volume of water within the enclosure was calculated as follows:

| | |
|---|---|
| Total Enclosed Volume: | (14 ft)(43 ft)(8 ft) = 4,816 $ft^3$ |
| Displaced Volume: | (15 tons)(2,000 pounds per ton) / 64 pounds per $ft^3$ = 468 $ft^3$ |
| Actual Volume Enclosed: | 4,816 $ft^3$ - 468 $ft^3$ = 4,348 $ft^3$ |
| Converting to Metric: | (4,348 $ft^3$)(7.48 gal per $ft^3$)(3.785 liters per gal) = $1.23 \times 10^5$ liters |

Using the highest concentration in the enclosure (1.55 mg/L) and subtracting the initial concentration within the enclosure prior to cleaning (0.02 mg/L), the total amount of copper released during the hull cleaning was ($1.23 \times 10^5$ liters)(1.53 mg/L) = $1.88 \times 10^5$ mg or 0.188 kg of copper.

This estimated mass of copper released in the Newport Bay enclosure study of 1991 correlates quite well with the estimated mass of 0.173 kg released from the pleasure craft studied in San Diego Bay as described above. This provides an increased level of confidence that the estimates for San Diego Bay are reasonable.

One other study of in-water hull cleaning was identified during the course of the investigation. The State of Washington Department of Ecology conducted studies of in-water hull cleaning in 1993 and 1994. Analysis of water samples documented that Washington water quality standards were exceeded (State of Washington 1995). However, information regarding the location of sample collection and size of the visually observed plume was not provided. Consequently no quantitative estimate of the total mass of copper released can be calculated.

Table 3-1 contains the estimated plume volume for each type of vessel. The total annual load of copper to San Diego Bay from in-water hull cleaning of civilian (non-Navy) vessels is given in Table 3-1 as 12,517 kg and for all vessels as 12,747 kg.

TABLE 3-1

## COPPER LOADING TO SAN DIEGO BAY
## ESTIMATE OF ANNUAL DISCHARGE OF COPPER FROM IN-WATER HULL CLEANING

| Vessel Type | Number of Vessels | Hull Cleaning Events per vessel per Year | Fraction of Vessels With Copper AF Paint | Area of Plume per Vessel ($m^2$) | Depth of Plume (m) | Volume of Plume per Vessel ($m^3$) | Maximum Concentration of Copper in Water (ug/L) | Annual Copper Discharged (kg) |
|---|---|---|---|---|---|---|---|---|
| US Navy Carriers | 2 | 0.5 | 1.00 | 13,473 | 12 | 161,676 | 131.3 | 21 |
| US Navy Submarines | 8 | 0.5 | 1.00 | 2,677 | 12 | 32,124 | 131.3 | 17 |
| US Navy Surface* | 72 | 0.4 | 1.00 | 3,645 | 12 | 43,740 | 131.3 | 165 |
| US Navy Tugs and Other | 80 | 0.5 | 0.95 | 452 | 12 | 5,424 | 131.3 | 27 |
| | | | | | | | **US Navy Total** | **230** |
| Pleasure/Small Commercial | 7,165 | 10.0 | 0.95 | 363 | 6 | 2,178 | 79.3 | 11,756 |
| Cruise and Passenger | 14 | 0.5 | 1.00 | 3,645 | 12 | 43,740 | 79.3 | 24 |
| Cargo | 148 | 0.5 | 1.00 | 4,849 | 12 | 58,188 | 79.3 | 341 |
| Barges | 25 | 0.5 | 1.00 | 1,720 | 12 | 20,640 | 79.3 | 20 |
| Tug Boats | 19 | 0.5 | 1.00 | 1,720 | 12 | 20,640 | 79.3 | 16 |
| Marine Construction | 10 | 0.5 | 1.00 | 2,519 | 12 | 30,228 | 79.3 | 12 |
| Miscellaneous and Visiting | 290 | 0.5 | 1.00 | 2,519 | 12 | 30,228 | 79.3 | 348 |
| | | | | | | | **Other Vessels Total** | **12,517** |
| | | | | | | | **Total Annual Copper Discharged by In-Water Hull Cleaning (kg)** | **12,747** |

Notes:

* Fraction 0.4 represents 29 of 72 surface vessels cleaned per year (Valkirs and others 1994)

AF Antifouling
$m^3$ Cubic meters
kg Kilograms
m Meter
ug/L Micrograms per liter
$m^2$ Square meters

result in release of substantially greater quantities of copper to the bay than those observed (McPherson 1995).

The calculation for pleasure and small commercial craft in Table 3-1 is:

| | |
|---|---|
| Number of Vessels: | 7,165 |
| Fraction With Copper Paint: | 0.95 |
| Hull Cleanings | 10 per year per vessel |
| Average Length and Width: | 12.2 m by 3 m (each vessel) |
| Hull Cleaning Plume Volume: | (6 m + 12.2 m + 6 m)(6 m + 3 m + 6 m)(6 m in depth*) |
| | = 2,178 $m^3$ (each cleaning) |
| Plume Copper Concentration: | (83 $\mu$g/L - 3.7 $\mu$g/L [Bay Background]) |
| | = 79.3 $\mu$g/L |
| Annual Copper Load. | (7,165)(0.95)(10)(2,178 $m^3$ each)(79.3 $\mu$g/L)($10^{-9}$ kg/$\mu$g)($10^3$ L/$m^3$) |
| | = 11,756 kg per year |

*The typical depth of water in the enclosed yacht and boat basins.

The total annual copper load from pleasure and small commercial vessel in-water hull cleaning (11,756 kg/year) represents a mass of copper of 0.173 kg released per 12.2 m (40.5 foot) pleasure craft per cleaning event.

The Santa Ana RWQCB conducted a similar study in Newport Bay in 1991 (Santa Ana RWQCB 1991). The primary difference between this in-water hull cleaning study and the San Diego Bay study was that the vessel used in the Newport Bay study was enclosed in an impermeable liner constructed of a rectangular polyethylene bag supported by polyvinyl chloride (PVC) pipe and weighted with sand bags. This liner (14 feet by 43 feet by 8 feet deep) enclosed a 38 foot Bertram pleasure craft. The report indicates that (1) five water samples were collected from within the liner after the in-water hull cleaning; (2) the ambient Newport Bay water concentration was 0.01 milligrams per liter (mg/L) copper before cleaning; and (3) two water samples collected inside the liner prior to cleaning contained 0.02 mg/L copper. The five samples collected from within the liner after cleaning contained between 0.52 and 1.55 mg/L copper. The report does not indicate whether the laboratory data represent total or

Plume Copper Concentration: (135 $\mu$g/L - 3.7 $\mu$g/L [Bay Background])
= 131.3 $\mu$g/L

Annual Copper Load: (72 vessels)(0.4 cleanings per vessel per year)(43,738 $m^3$ each)(131.3 $\mu$g/L)
= (165x$10^6$ $\mu$g $m^3$ /L year) ($10^{-9}$ kg/$\mu$g)($10^3$ L/$m^3$)
= 165 kg per year

The number and class of nuclear submarines homeported in San Diego Bay were obtained from Lt. Dan Hernandez, the Point Loma Submarine Base public affairs officer (Hernandez 1996). One Sturgeon Class and seven Los Angeles Class submarines and a submarine tender were used to estimate copper antifouling paint contributions from the Point Loma Submarine Base. The submarine wetted hull areas were estimated based on dimensions given in "Modern Submarine Warfare" (Miller 1987) and by assuming that approximately 66 percent (2/3) of each submarine is submerged while at pier side. A Los Angeles class submarine is 360 feet long with a beam of 33 feet, the Sturgeon is slightly smaller. For the purposes of conservative estimation, the Sturgeon was assumed to have the same wetted hull surface area as the Los Angeles submarines. The submarines were conservatively assumed (ignoring any hull tapering) to be right circular cylinders 33 feet in diameter and 360 feet long with 25,000 square feet ($ft^2$) of wetted hull area each at pier side. The tender wetted hull surface area is accounted for with other Navy surface vessels. A floating dry-dock, normally secured at the Point Loma Submarine Base, is currently in use in Pearl Harbor, Hawaii, and is due to return to San Diego in 1997 (Hernandez 1996). It has not been factored into the copper loading calculations; however the copper load from the dry-dock, upon arrival, is estimated to be similar to that of an average Navy surface vessel.

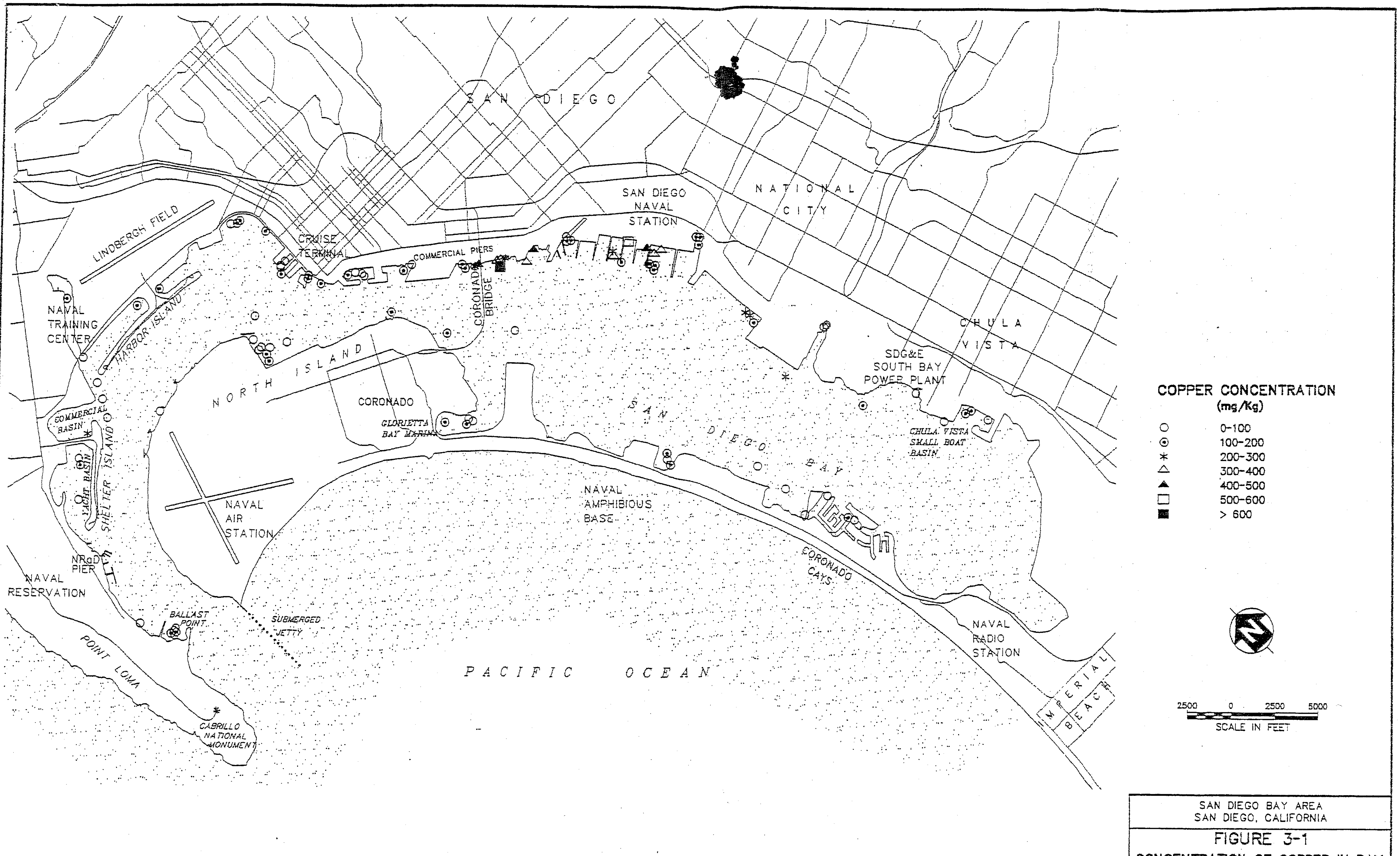
### 3.2.2 In-water Hull Cleaning—All Other Vessels

The in-water hull cleaning copper release estimates for vessels not controlled by the Navy are also contained in Table 3-1. Information regarding the average lengths and numbers of private and commercial vessels in the bay was obtained from the San Diego Unified Port District Harbor Police 1995 Yacht Club/Marina/Boat Yard/Anchorage Annual Survey (Port 1995) and Assistant Director of Marine Operations, Paul Libuda (Libuda 1996). The annual survey is presented in Appendix B. The number of in-water hull cleaning events and the fraction of vessels with copper-containing antifouling hull paints were estimated from data provided in "Marine Fouling and Underwater Hull Cleaning in San Diego Bay" (Conway 1994).

The fraction of pleasure craft with copper-containing antifouling hull paint was reduced from 1.00 to 0.95 to account for vessels which are not painted with copper containing antifouling paints. This includes pleasure craft with aluminum hulls which are painted with tributyltin (TBT)-containing antifouling paints because copper cannot be used on aluminum hulls due to severe corrosion problems. TBT antifouling paints often also contain copper. However, copper-free TBT antifouling paints are available in both the U.S. and Mexico, generally for use on aluminum-hulled vessels. Discussions with San Diego Bay mariners suggest that up to 10 percent of San Diego Bay pleasure craft may use Mexican port facilities for application of antifouling paint and that some of this paint is copper-free, TBT-containing antifouling hull paint.

The hulls of large commercial vessels are not often cleaned in San Diego Bay, according to Mr. Libuda, because they typically average only a 1.5-day stay to unload cargo or conduct business before returning to sea. Additionally, large commercial vessels are often maintained in non-U.S. ports where labor and other costs are lower than in San Diego. Data in Table 3-1 were therefore adjusted by assuming that the number of hull cleaning events for cargo, barges, and miscellaneous vessels with copper antifouling paint is 0.5 rather than one hull cleaning per vessel per year.

The maximum copper concentration of 83 $\mu$g/L out of 18 plume sample analyses results reported in McPherson (1995) during a study of the effects of a private pleasure craft in-water hull cleaning event in Shelter Island Yacht Basin of San Diego Bay for the San Diego RWQCB was used for non-Navy vessels in this study, corrected for the bay background concentration of 3.7 $\mu$g/L. The study involved collection of samples prior to, during, and following an underwater hull cleaning operation carried out by a professional diver hand wiping with new, plastic-fiber scrubbing pads using best management practices. The vessel was a Concept 30 power boat measuring 30 feet in length, 9 feet in width, and with a 2.5 foot draft. The report indicates that (1) the cleaning took approximately 25 to 30 minutes with sampling occurring every 5 minutes for a total of 11 samples; (2) the hull of the boat was not heavily fouled; (3) because the samples were taken from different locations around the boat, contaminant concentrations in 11 samples were independent of each other, ranging from 40 $\mu$g/L to 83 $\mu$g/L; and (4) cleaning of more heavily fouled boats using more vigorous removal techniques could

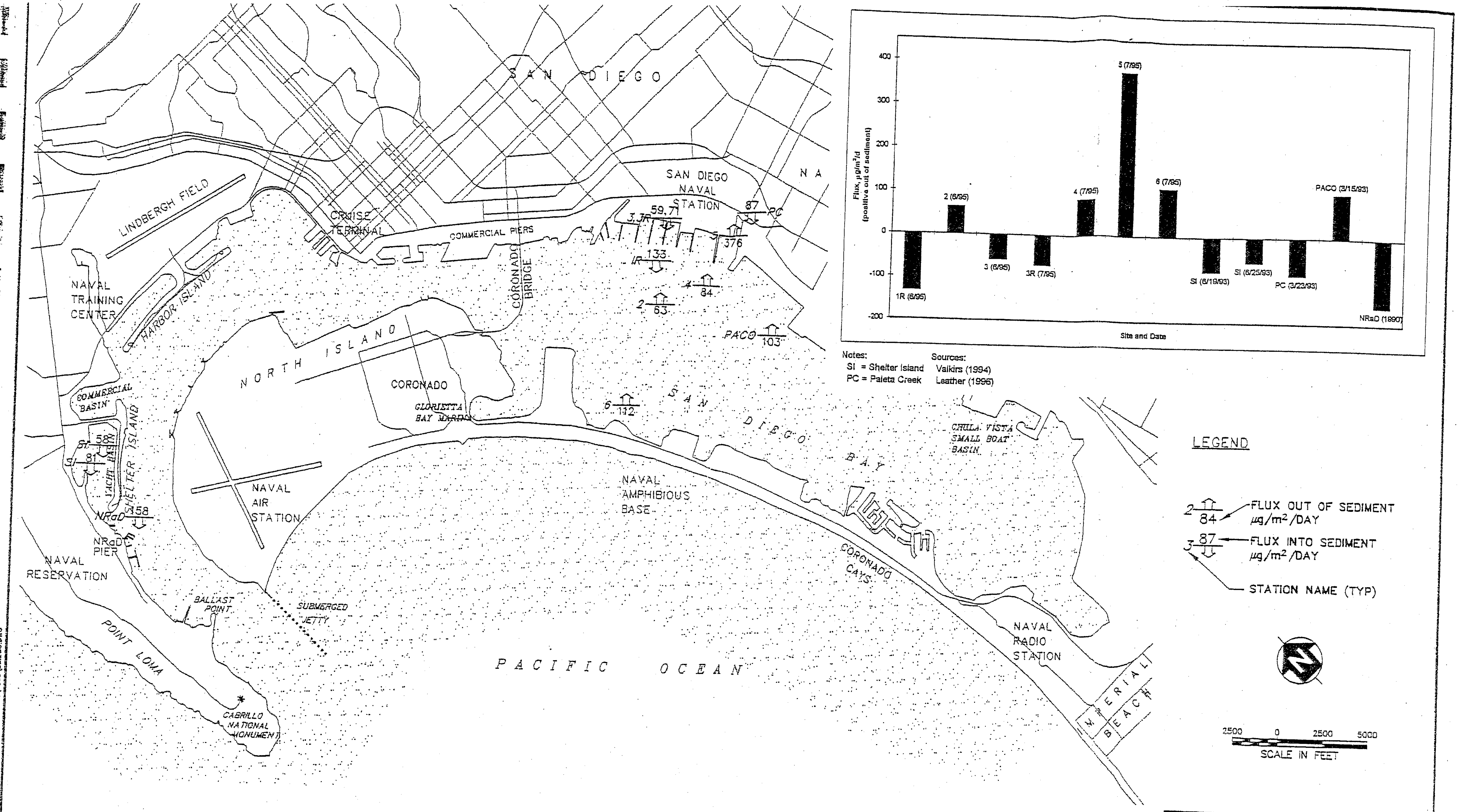



SOURCE: CALIFORNIA DEPARTMENT OF FISH AND GAME (1995)

SAN DIEGO BAY AREA
SAN DIEGO, CALIFORNIA

FIGURE 3-1
CONCENTRATION OF COPPER IN BAY SEDIMENT (10/92 - 3/94)

PRC ENVIRONMENTAL MANAGEMENT, INC.




SOURCE: LEATHER 1996
VALKIRS AND OTHERS (1994)

SAN DIEGO BAY AREA
SAN DIEGO, CALIFORNIA

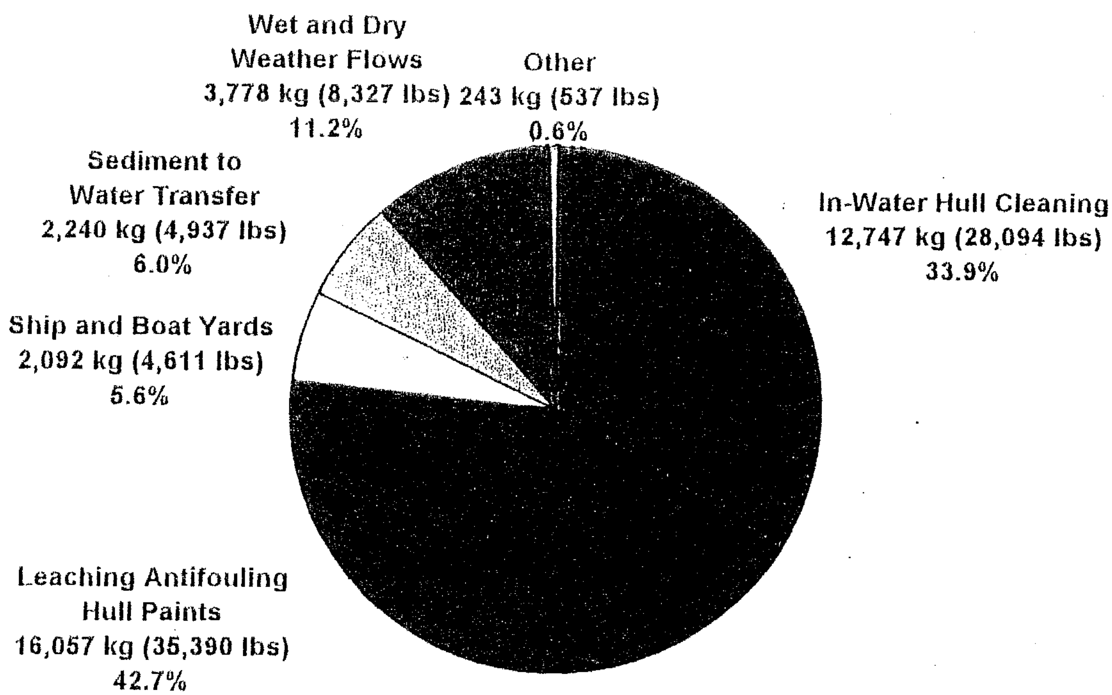
FIGURE 3-2
FLUX RATE MEASUREMENTS OF COPPER

PRC ENVIRONMENTAL MANAGEMENT, INC.

Bat ... 93-...

FIGURE 4-1

WASTE COPPER LOADING TO SAN DIEGO BAY
BREAKDOWN OF ESTIMATED ANNUAL COPPER LOADING




Notes:
1. Wet and dry weather flows data from Woodward-Clyde Consultants (WCC) 1996.
2. Other includes 181 kg from San Diego Gas and Electric plant, 21 kg from rainfall, and 41 kg from atmospheric deposition
kg Kilograms
lbs Pounds

- The limited sediment data from Commercial Basin was used to estimate an average sediment concentration in the basin and the total load in the basin was allocated equally to the four boatyards. The Commercial Basin data was used to estimate the copper load to the bay from the South Bay Boatyard.

## 4.3 SAN DIEGO BAY TIDAL FLUSHING AND TIDAL PRISM MODEL

This section describes the tidal flushing characteristics of San Diego Bay and presents a simple tidal prism model to estimate the volume of water exchanged with the Pacific Ocean on an annual basis. This tidal prism model can be used to estimate the amount of copper discharged to the Bay annually, based on the estimated copper concentration in the Bay and in southern California coastal seawater.

### 4.3.1 San Diego Bay Tidal Flushing

In a study addressing the distribution and fate of organotins from antifouling paints in U.S. harbors (Grovhoug and others 1987), San Diego Bay was described as a semi-enclosed water body extending approximately 28 km in length and varying from 0.5 to 4.6 kilometers (km) in width, with a depth of generally less than 4.5 meters (m). The bay configuration allows tidal flows that are strong at the mouth (Point Loma) and exponentially decreasing towards the back or south bay.

Near the mouth, approximately 40 percent of the water brought in by the average flood tide is new, uncontaminated ocean water, while near the Coronado bridge only 4.2 percent is new water. Therefore, complete tidal flushing for the south bay would require more than 40 days, whereas flushing at the entrance of the bay may only require 1 to 2 days. The exchange drops off rapidly as a function of distance from the mouth (Chadwick and others 1995). In the absence of other measured data, the tidal exchange rate was extrapolated in a linear fashion. Though the data indicate that there is a logarithmic relationship between exchange rate and distance from the mouth, a linear extrapolation was chosen because the south bay is significantly more shallow (9 feet estimated average depth) than the rest of the bay (30 to 40 feet). The whole bay average period for complete tidal flushing is 5.6 days (Chadwick and others 1995). Subembayments such as the Shelter Island yacht harbor, Glorietta Bay, Coronado Cays, and the Harbor Island yacht harbor receive less flushing than the main bay channel section adjacent to each subembayment.

### 4.3.2 Tidal Prism Model

A study of San Francisco Bay (Chen and others 1996) has utilized a link node approach to model copper concentrations based on numerous point sources. This approach, when coupled with a complete, validatable data set, can provide a more sophisticated understanding of the dynamics of multiple sources, tidal action, and riverine input. However, for the purposes of this study, a simpler tidal prism model has been selected to estimate the total volume of water exchanged between the Bay and the ocean on an annual basis. In summary, the average volume of water exchanged per tide (Chadwick 1996), the fraction of former bay water recycled (0.4) on each tide, and the number of tides per year can be used to calculate the annual volume of water discharged from the Bay. The calculation is presented below.

Annual Volume Exchanged (V):

$$V = (1 - f)(Tp)(n)$$
$$= (1 - 0.4)(7.4\times10^{7}\ m^3 \text{ per tide})(701 \text{ tides per year})$$
$$= 3.1\times10^{10}\ m^3 \text{ per year}$$

Where:
- $f$ = fraction of Bay water returning in each tide
- $1-f$ = Percentage of new, uncontaminated ocean water
- $Tp$ = Volume of water exchanged per tide
- $n$ = Number of tides per Year

The mass of copper discharged from the Bay on annual basis can then be calculated as follows.

Annual Mass of Copper ($M_{cu}$): Tidally Discharged from San Diego Bay

$$M_{Cu} = V([Cu]_{Bay} - [Cu]_{Ocean})$$
$$= (3.1\times10^{10}\ m^3 \text{ per year})(3.7 - 2.0\mu g/L)(1000L/m^3)(kg/10^9\ \mu g)$$
$$= 52{,}700 \text{ kg per year } (116{,}151 \text{ pounds per year})$$

Where:
- $[Cu]_{Bay}$ = average copper concentration in San Diego Bay water
- $[Cu]_{Ocean}$ = average southern California coastal copper concentration

Note that the $M_{cu}$ estimate increases by 31,000 kg for every 1 $\mu$g/L change in $[Cu]_{Bay}$ - $[Cu]_{Ocean}$. This estimate of the amount of copper transferred by the tidal exchange is helpful when comparing gross trends and quantities of other copper sources in the bay. It should also be noted that this estimate of the mass of copper discharged annually is extremely sensitive to the estimates of both southern California coastal ocean and San Diego Bay average water copper concentrations.

- The limited sediment data from Commercial Basin was used to estimate an average sediment concentration in the basin and the total load in the basin was allocated equally to the four boatyards. The Commercial Basin data was used to estimate the copper load to the bay from the South Bay Boatyard.

## 4.3 SAN DIEGO BAY TIDAL FLUSHING AND TIDAL PRISM MODEL

This section describes the tidal flushing characteristics of San Diego Bay and presents a simple tidal prism model to estimate the volume of water exchanged with the Pacific Ocean on an annual basis. This tidal prism model can be used to estimate the amount of copper discharged to the Bay annually, based on the estimated copper concentration in the Bay and in southern California coastal seawater.

### 4.3.1 San Diego Bay Tidal Flushing

In a study addressing the distribution and fate of organotins from antifouling paints in U.S. harbors (Grovhoug and others 1987), San Diego Bay was described as a semi-enclosed water body extending approximately 28 km in length and varying from 0.5 to 4.6 kilometers (km) in width, with a depth of generally less than 4.5 meters (m). The bay configuration allows tidal flows that are strong at the mouth (Point Loma) and exponentially decreasing towards the back or south bay.

Near the mouth, approximately 40 percent of the water brought in by the average flood tide is new, uncontaminated ocean water, while near the Coronado bridge only 4.2 percent is new water. Therefore, complete tidal flushing for the south bay would require more than 40 days, whereas flushing at the entrance of the bay may only require 1 to 2 days. The exchange drops off rapidly as a function of distance from the mouth (Chadwick and others 1995). In the absence of other measured data, the tidal exchange rate was extrapolated in a linear fashion. Though the data indicate that there is a logarithmic relationship between exchange rate and distance from the mouth, a linear extrapolation was chosen because the south bay is significantly more shallow (9 feet estimated average depth) than the rest of the bay (30 to 40 feet). The whole bay average period for complete tidal flushing is 5.6 days (Chadwick and others 1995). Subembayments such as the Shelter Island yacht harbor, Glorietta Bay, Coronado Cays, and the Harbor Island yacht harbor receive less flushing than the main bay channel section adjacent to each subembayment.

With this caveat, the estimated mass of copper discharged from the Bay agrees reasonably well with the total annual estimated copper loading for the bay 37,589 kg per year (82,818 pounds per year). If, however, for instance, the Valkirs and others (1994) average baywide copper concentration (3.3 $\mu$g/L) is used in conjunction with the coastal estimate of 2.0 $\mu$g/L (VanderWeele 1996) then the mass of copper tidally discharged would be estimated as 40,300 kg per year (88,160 pounds per year), an estimated mass of copper in good agreement with the mass of copper (37,589 kg per year) loading for San Diego Bay estimated in this study.

# 5.0 RECOMMENDATIONS

The following are recommendations for further research associated with copper loading to San Diego Bay:

- Identify additional sources of copper, such as condensers and salt water heat exchanger systems other than the SDG&E South Bay Power Plant
- Quantify release rates of copper from private and commercial vessel hulls
- Identify the frequency of hull cleaning of large commercial vessels in San Diego Bay
- Collect additional data on sediment to water copper transfer
- Apply more sophisticated total daily maximum load models such as the link node model of copper in San Francisco Bay (Chen and others 1996)
- Collect data regarding copper concentrations in the water column throughout the bay including both source and background areas
- Collect offshore copper concentration data from coastal southern California ocean waters to estimate background copper concentration since all models will be extremely sensitive to the ocean background copper concentration input

( ADD RECOMMENDATION
DATA GAP ... DRY WEATHER FLOWS )

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# APPENDIX A
# WCC REPORT OF NONPOINT SOURCE COPPER

# SAN DIEGO BAY
# COPPER WASTE LOAD DETERMINATION STUDY: CONTRIBUTION OF COPPER FROM STORM WATER RUNOFF AND DRY WEATHER FLOWS

## INTRODUCTION

The following sections present a summary of the approach and methodology used to estimate copper loading to San Diego Bay from storm water runoff and dry weather flows. Annual copper loading from storm water (wet-weather) flows were estimated using a watershed-based spreadsheet calculation. First, the 10 sub-watersheds draining into San Diego Bay were defined in terms of area, land uses, and annual precipitation. Annual copper loads were then calculated based on annual precipitation, percent pervious and impervious (by land use), area of watershed, and mean value of copper measured at land use-specific sampling locations. Total loading to San Diego Bay from storm water runoff was then calculated as the sum of the contributions from each watershed. Because loadings estimates were developed based on monitoring stations located upstream of the highly developed bayside industries (e.g., Naval facilities, airport, shipyards), an additional estimate was calculated for copper in runoff from these bayside industries. More details concerning the methodology used and results are presented below.

Contributions of copper from dry weather flows potentially includes discharges from NPDES permitted industries along the Bay (including shipyards and dewatering facilities), releases from upland reservoirs (e.g., Sweetwater, Loveland, and Otay Lakes), groundwater base flows, and incidental and/or illegal discharges to the storm drain system (e.g., from residential car washing, illegal dumping, improper plumbing connections, etc.). One very large potential source of dry weather pollutants including copper in many urban areas is NPDES permitted discharges. However, in San Diego the vast majority of these discharges have been eliminated since 1964 (most such discharges flow into the sanitary sewer and discharge via the deep ocean outfall; Bloom, 1995). Due to the paucity of data and intermittent nature of the other discharges, calculation of a firm loading estimate for copper from dry weather flows is difficult. Consequently, loadings from these sources are presented in ranges (minimum and maximum credible copper loadings estimates). More detailed discussion of potential dry weather sources is provided below.

## ESTIMATION OF POLLUTANT LOAD FROM WET-WEATHER FLOWS THE DRAINAGE AREA

This section provides estimates of pollutant loads from storm water runoff from each of the 10 watersheds in the study area. Event Mean Concentrations (EMCs) calculated from three years of flow-weighted composite monitoring results from the City of San Diego and Co-permittees NPDES Stormwater Monitoring Program (1993 through 1996) were used to estimate the copper load for residential, commercial, and industrial land use categories into San Diego Bay. Park/open space and agriculture land uses were not monitored during the City of San Diego and

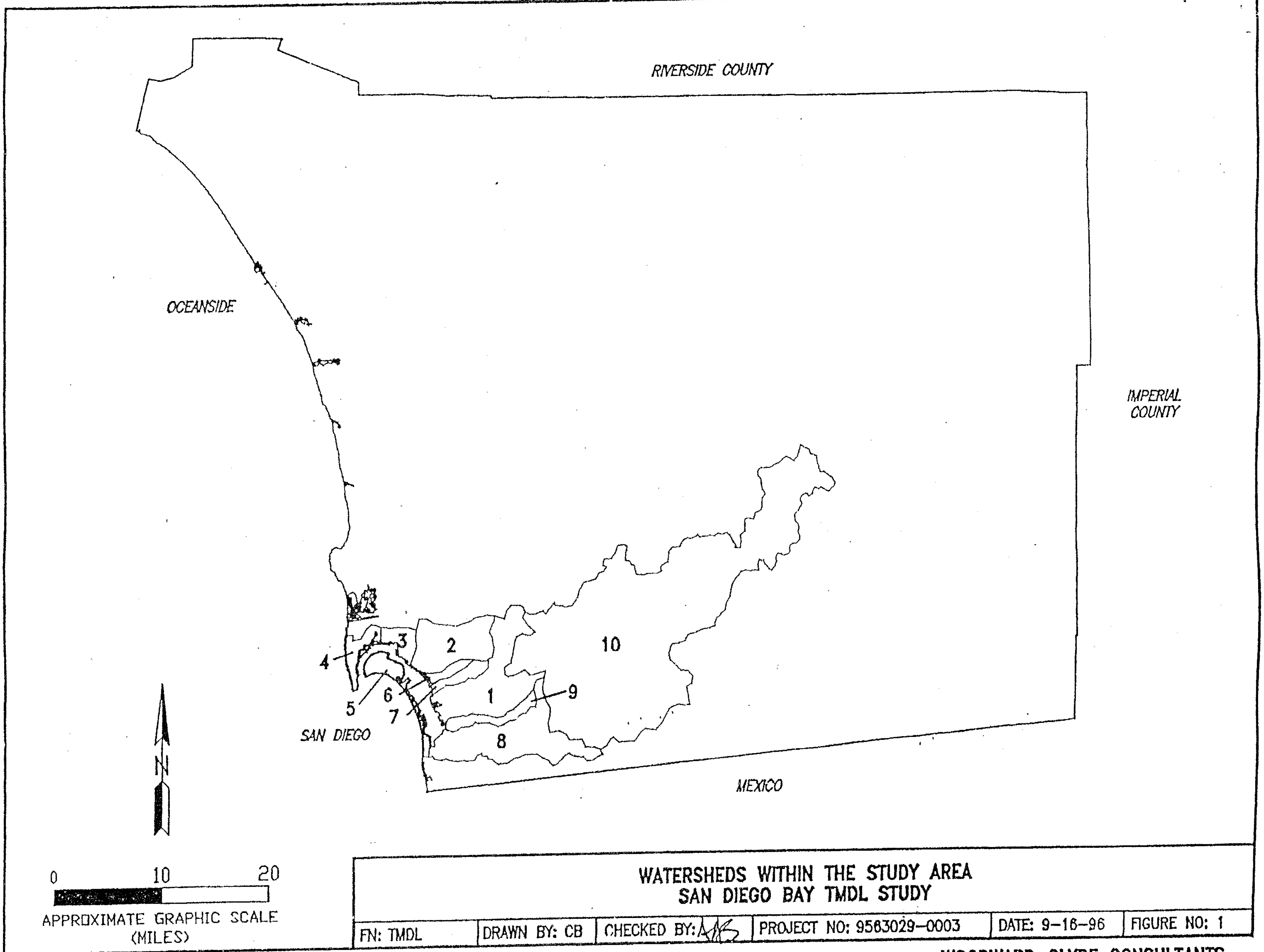
Co-permittees Stormwater Monitoring Program or for any other known storm water studies in the San Diego region; therefore, no local data were available for copper load modeling. EMCs for park/open space and agriculture land uses were based upon flow-weighted composite monitoring conducted in the Santa Clara Valley and San Francisco Bay Area Stormwater Monitoring Programs. Although San Francisco Bay area data are not presumed to be identical to San Diego area data, they are the most current data available from California. Data from the Federal Highway Administration were utilized to estimate runoff quality from transportation corridors (U.S. Federal Highways Administration, 1990).

Copper loads were calculated using a Microsoft Excel Version 5.0 Spreadsheet model. The spreadsheet was used to estimate annual runoff pollution loads for total and dissolved copper. This model was used to estimate typical urban runoff quality in each of the 10 San Diego Bay watersheds using calculated and published EMCs, precipitation data, and land use data for the 10 watersheds provided in the San Diego Association of Government's (SANDAG) geographical information system (GIS; SANDAG, 1990).

## Watershed Delineation

The SANDAG GIS database was used to define watersheds within the study area. A total of 10 sub-watersheds draining into San Diego Bay were delineated and assigned numerical values (Figure 1). The watersheds draining into San Diego Bay extend from the ridge line running along the summit of the Laguna Mountains in eastern San Diego County westward to the Bay itself. The portions of the watersheds located east of the urbanized areas of the county (approximately all lands to the east of the upland reservoirs) consist predominately of open space (Watershed No. 10). Watersheds 1 through 9 are located within the urbanized portion of the county, in the portion of the county monitored as part of the City of San Diego and Co-permittee NPDES Stormwater Monitoring Program. Watersheds for the mass loading stations established for this monitoring program were separately delineated since the locations of the monitoring sites did not always sample an entire watershed due to factors such as tidal influence in the lower reaches. In addition, the SANDAG watersheds consider two of the mass loading stations on Switzer and Chollas Creeks, to be part of a single watershed (Watershed 2 on Figure 1).

The hydrology of the upper San Diego Bay watershed area (Watershed 10) is controlled to a significant extent by the reservoirs constructed along the base of the foothills (Sweetwater and Loveland Reservoirs, located on the Sweetwater River and operated by the Sweetwater Authority, and upper and lower Otay Lakes, on the Otay River and operated by the City of San Diego, Department of Water Utilities). The other nine watersheds are located downstream of the reservoirs. The two water agencies regulate flow out of the reservoirs through planned releases that occur mainly in the winter, during the rainy season. Because all flow through the Sweetwater and Otay River systems passes through the reservoirs, the reservoirs effectively serve as settling basins for removing suspended solids present in the flow. Since a large percentage of copper present in the "total" fraction is adsorbed to sediments, this trapping likely results in a reduction in the copper load that ultimately reaches San Diego Bay.




| | | | | |
|---|---|---|---|---|
| WATERSHEDS WITHIN THE STUDY AREA<br>SAN DIEGO BAY TMDL STUDY | | | | |
| FN: TMDL | DRAWN BY: CB | CHECKED BY: [signature] | PROJECT NO: 9563029-0003 | DATE: 9-16-96 | FIGURE NO: 1 |

WOODWARD-CLYDE CONSULTANTS

To account of this reservoir reduction effect, we ran the model two different ways. In the first run, we included the portions of the San Diego Bay watershed above the reservoirs (Watershed 10) in addition to the nine watersheds downstream of the reservoirs. This result yields the highest probable copper load from storm water. In the second run, we excluded Watershed 10 and modeled the copper load in runoff from Watersheds 1 through 9 only. (This result assumes that the reservoirs retain all copper originating in the watershed above the reservoirs.) The true loading from storm water is believed to lie between these two results.

## Land Use Categories and Mapping

Land use data were obtained from the SANDAG GIS database showing 1990 Generalized Land Uses for the San Diego urbanized area. The land use classifications used by SANDAG were aggregated into six categories: residential, industrial, commercial, park/open space, agriculture and roadways. The total acreage of each land use in each of the 10 watersheds is summarized in Table 1.

The SANDAG GIS database was also used to assess land use within the catchments of the two mass loading stations. Land uses within the monitored portions of these watersheds are summarized in Table 2.

## Other Model Inputs

Other model inputs include the percentage of impervious land coverage within each land use category and EMCs for each land use. Input values used in each model are summarized in Table 3. Percent impervious values were based upon literature values and data from similar studies throughout California. The EMCs were calculated from results obtained from the last three monitoring years for residential, commercial, industrial land use categories. EMCs for parks and open land were based upon Santa Clara Valley and San Francisco Bay Area values. Federal Highway Administration data (U.S. Federal Highways Administration, 1990) were used for roadways. For this analysis, pervious areas were assumed to have a runoff coefficient of 0.20 and impervious areas 0.95.

Long-term isohyets were used to estimate average rainfall for drainage basins 1 through 9, Table 4. Because of wide range of precipitation in drainage basin 10, 11 to 35 inches per year, an average rainfall of 14 inches per year was estimated for drainage basin 10, from County of San Diego Hydrology Manual (revised 1985), to better represent precipitation in the valleys and river basins.

## Copper Sources

In general, the concentration of copper tends to be higher in runoff from urbanized areas than from open space (Woodward-Clyde Consultants, 1996). Results from storm water monitoring conducted in San Francisco Bay Area between 1988 and 1995 suggest that although there are minor differences between runoff from different categories of urban use, land use is not a

## Table 1
## TOTAL ACREAGE OF EACH LAND USE BY SAN DIEGO BAY WATERSHED

| Watershed Basin Number | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Commercial | Park/Open Space | Agriculture | Roads | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1,262 | 12,492 | 1,670 | 989 | 1,282 | 6,828 | 875 | 655 | 26,053 |
| 2 | 2,008 | 10,453 | 2,066 | 210 | 1,162 | 2,972 | 229 | 1,168 | 20,268 |
| 3 | 538 | 627 | 1,042 | 366 | 646 | 518 | 5 | 905 | 4,647 |
| 4 | 147 | 1,505 | 967 | 0 | 98 | 1,064 | 21 | 30 | 3,832 |
| 5 | 297 | 1,011 | 1,790 | 9 | 73 | 616 | 256 | 785 | 4,837 |
| 6 | 92 | 1,062 | 493 | 0 | 105 | 126 | 0 | 109 | 1,987 |
| 7 | 285 | 1,962 | 565 | 7 | 284 | 302 | 9 | 69 | 3,483 |
| 8 | 900 | 4,152 | 1,131 | 2,422 | 503 | 12,980 | 6,347 | 733 | 29,168 |
| 9 | 239 | 1,660 | 297 | 488 | 207 | 601 | 1,577 | 182 | 5,251 |
| 10* | 0 | 9,175 | 436 | 0 | 505 | 159,547 | 9,139 | 532 | 179,334 |
| TOTAL | 5,768 | 44,099 | 10,021 | 4,491 | 4,865 | 185,554 | 18,458 | 5,168 | 278,860 |

* Watershed lands above reservoirs

## Table 2
## EXISTING LAND USE DISTRIBUTION WITHIN MONITORED MASS LOADING WATERSHEDS

| Land Use | Mass Loading Watersheds | | | | |
|---|---|---|---|---|---|
| | Switzer | | North Fork Chollas Creek | | Total Acreage |
| | Acres | Percent | Acres | Percent | |
| Residential | 1,160 | 47 | 5,811 | 62 | 6,971 |
| Commercial | 201 | 8 | 879 | 9 | 1,080 |
| Industrial | 274 | 11 | 931 | 10 | 1,205 |
| Agriculture | 153 | 6 | 34 | <1 | 187 |
| Open/Parks | 509 | 21 | 1,264 | 14 | 1,773 |
| Roadways | 157 | 6 | 434 | 5 | 591 |
| Total | 2,454 | 100 | 9,353 | 100 | 11,807 |

## Table 3
## COPPER EMC INPUT FOR EACH LAND USE CATEGORY

| Land Use | Percent Impervious | Total Cu (μg/l) (low/high) | Diss. Cu (μg/l) (low/high) |
|---|---|---|---|
| Park & Open/Undeveloped[a] | 0.5% | 12.0/20.0 | 7.2/12.0[b] |
| Agriculture[a] | 0.5% | 12.0/20.0 | 7.2/12.0[b] |
| Residential | 13.9% | 27.6 | 22.7[b] |
| Commercial | 90.0% | 18.9 | 12.8 |
| Industrial | 73.7% | 24.7 | 24.0 |
| Roadway[c] | 90.0% | 52.0 | 42.8[b] |

Notes:

a Based on San Francisco Bay Area data (Woodward-Clyde, 1991)

b Estimated using the relationship observed between the measured total and dissolved metals concentration for the commercial and industrial land use sites in study area from 1993/94 to 1995/96. Total to dissolved conversion factor used was 82% for copper.

c Based on Federal Highway Administration, "Pollutant Loading and Impacts from Highway Stormwater Runoff, Volume 3; Analytical Investigation and Research Report," FHWA-RD-88-008, McLean, Virginia, April 1990.

Table 4
ESTIMATED AVERAGE ANNUAL PRECIPITATION
FOR EACH WATERSHED BASIN IN DRAINAGE AREA

| Watershed Basin Number | Annual Precipitation (Inches) |
|---|---|
| 1 | 11.50 |
| 2 | 11.30 |
| 3 | 10.40 |
| 4 | 10.80 |
| 5 | 11.00 |
| 6 | 10.60 |
| 7 | 10.60 |
| 8 | 12.50 |
| 9 | 11.70 |
| 10 | 14.00 |

significant factor in determining the concentration of copper in storm water runoff (Woodward-Clyde Consultants, 1996). The sources of copper in urban areas include the following: residues from brake pad wear, tire wear, clutch pad wear, vehicle servicing (used oil), oil/coolant leaks, car washing, outdoor cleaning, outdoor metals storage, pesticide use, cooling water discharge, illegal dumping, copper pipe corrosion, runoff from copper roofs and gutters, industrial site runoff, erosion of hillsides and stream banks, air pollution deposition, and discharges from water supply and swimming pools, spas, and fountains (copper sulfate; Brake Pad Partnership Forum, 1996). Sources of copper in runoff from parks and open space include weathering of minerals and soils, erosion, and residuals from pesticides and herbicides.

In regard to brake pad wear, studies of the most common 80% of brake pad types revealed that brake pads consist of 0 to 20% copper, which wears down and is deposited on pavement through use [Santa Clara Valley Nonpoint Source Control Program, (Woodward-Clyde, 1994)]. Based on these studies, brake pad wear may account for up to 63% of the copper observed in storm water runoff. More studies are necessary to confirm these estimates.

## Model Results

Table 5A summarizes the results for all 10 watersheds in the study area. Table 5B summarizes the results for Watersheds 1 through 9. Appendix A presents pollutant load calculations for each individual watershed. The watershed-specific EMCs were calculated based upon the percentage of each land use in the catchment and the EMCs utilized for each land use. As mentioned above, the model was run two ways:

## Table 5A
## ESTIMATED AVERAGE ANNUAL COPPER LOAD FOR EACH MODELED PARAMETER FOR ENTIRE DRAINAGE AREA (WATERSHEDS 1 THROUGH 10)

| Parameter | Pollutant Load [kg/yr (lbs/yr)] | | | | | | Total Pollutant Load | |
|---|---|---|---|---|---|---|---|---|
| | Residential | Industrial | Commercial | Park/Open Space (low/high) | Agriculture | Roads | (low / high) (lbs/yr) | (low / high) (lbs/yr) |
| Total Copper | 473.2 kg (1,041 lb) | 460 kg (1,012 lb) | 129.1 kg (284 lb) | 640.5 kg (1,409 lb) / 1,067.7 kg (2,349 lb) | 60.9 kg (134 lb) | 280 kg (616 lb) | 2,043.6 kg / 2,470.1 kg | (4,496 lb / 5,436 lb) |
| Dissolved Copper | 415.9 kg (915 lb) | 318.6 kg (701 lb) | 65 kg (143 lb) | 383.2 kg (843 lb) / 638.6 kg (1,405 lb) | 36.4 kg (80 lb) | 167.7 kg (369 lb) | 1,386.8 kg / 1,642.3 kg | (3,051 lb / 3,613 lb) |

## Table 5B
## ESTIMATED AVERAGE ANNUAL COPPER LOAD FOR EACH MODELED PARAMETER FOR URBANIZED PORTIONS OF THE DRAINAGE AREA (WATERSHEDS 1 THROUGH 9)

| Parameter | Pollutant Load [kg/yr (lbs/yr)] | | | | | | Total Pollutant Load | |
|---|---|---|---|---|---|---|---|---|
| | Residential | Industrial | Commercial | Park/Open Space (low / high) | Agriculture | Roads | (low / high) (kg/yr) | (low / high) (lbs/yr) |
| Total Copper | 379.1 kg (834 lb) | 444.1 kg (977 lb) | 112.7 kg (248 lb) | 78.2 kg (172 lb)/ 130 kg (286 lb) | 28.6 kg (63 lb) | 245 kg (539 lb) | 1,288.2 kg/ 1,340 kg | 2,834 lb/ 2,948 lb |
| Diss. Copper | 333.6 kg (734 lb) | 307.7 kg (677 lb) | 56.8 kg (125 lb) | 46.8 kg (103 lb)/ 77.7 kg (171 lb) | 17.3 kg (38 lb) | 146.8 kg (323 lb) | 908.6 kg/ 939.5 kg | 1,999 lb/ 2,067 lb |

(1) To estimate total copper load originating in runoff from the entire San Diego Bay watershed, including the non-urbanized areas above the reservoirs (Watersheds 1 through 10); and

(2) To estimate copper load originating from the urbanized areas below the reservoirs only (Watersheds 1 through 9).

The following equation was used to estimate total runoff in acre-feet/year for each basin:

$$Q = \frac{A \times [(0.95 \times i) + (0.2 \times p)] \times P}{12}$$

Q = runoff volume, acre-ft/yr.

A = area of watershed basin, acres

i = percent impervious, dimensionless

p = percent pervious, dimensionless

P = annual precipitation, inches

Stormwater runoff from the 278,860-acre study area is estimated at 81,311 acre-feet per year (36,842 acre-feet per year from the 99,526 acres within Watersheds 1 through 9). This discharge typically contains large quantities of sediment, approximately $5.2 \times 10^6$ kg/yr (5,700 tons/year) of suspended solids from urbanized Watersheds 1 through 9. No sediment quantity data was available for Watershed 10. Sediments are associated with relatively high levels of trace metals including copper. Since sufficient data were not available for park/open land use from San Diego Monitoring Program, a low and high range of EMCs, 12 and 20 µg/l for total copper and 7.2 and 12 µg/l for dissolved copper, respectively, were used in the pollutant load model based on values from Santa Clara Valley and San Francisco Bay Area Stormwater Monitoring Programs, respectively. Annual load estimates from the entire study area (Watersheds 1-10) are 2,043.6 kg (4,496 lb) and 1,386.8 kg (3,051 lb) of total and dissolved copper, respectively, using the lower park/open land use EMC, and 2,470.1 kg (5,436 lb) and 1,642.3 kg (3,613 lb) park/open land use EMC. Using the high range EMC for park/open land increases the copper load to the Bay by 19 and 17 percent for total and dissolved copper, respectively.

Based on the modeling results for the entire watershed (Table 6A), using low range of EMC for park/open land from Santa Clara Valley Stormwater Monitoring Program, industrial land use represents approximately five percent of the study area but contributes approximately 23 percent of the total and dissolved copper load to the Bay. Residential land use represent less than eighteen percent of the study area and contributes approximately 23 and 30 percent of the total and dissolved copper load to the Bay, respectively. Together, commercial and industrial areas occupy only 7.1 percent of contributing watersheds but are estimated to contribute 29 and

28 percent of the total and dissolved copper, respectively. Park/open land covers three-quarters of the study area and contributes 31 and 28 percent of the total and dissolved copper, respectively. Roads cover just under 2 percent of the study area and are estimated to contribute approximately 14 and 12 percent of the total and dissolved copper load, respectively.

### Table 6A
### PERCENTAGE OF COPPER LOAD FROM EACH LAND USE BASED ON MODEL RESULTS (WATERSHEDS 1 THROUGH 10)

| Parameter / % Land Use | Residential (low/high) | Industrial (low/high) | Commercial (low/high) | Park/Open Space (low/high) | Agriculture (low/high) | Roads (low/high) |
|---|---|---|---|---|---|---|
| % Land Use | 17.9 | 5.4 | 1.7 | 66.5 | 6.6 | 1.9 |
| Total Copper | 23.1/19.1 | 22.5/18.8 | 6.3/5.2 | 31.3/43.2 | 3.0/2.5 | 13.7/11.3 |
| Dissolved Copper | 30.0/25.3 | 23.0/19.4 | 4.7/4.0 | 27.6/38.9 | 2.6/2.2 | 12.1/10.2 |

### Table 6B
### PERCENTAGE OF COPPER LOAD FROM URBANIZED PORTIONS OF WATERSHED BASED ON MODEL RESULTS (WATERSHEDS 1 THROUGH 9)

| Parameter / % Land Use | Residential (low/high) | Industrial (low/high) | Commercial (low/high) | Park/Open Space (low/high) | Agriculture (low/high) | Roads (low/high) |
|---|---|---|---|---|---|---|
| % Land Use | 40.9 | 14.6 | 4.4 | 26.1 | 9.4 | 4.7 |
| Total Copper | 29.4/28.3 | 34.5/33.2 | 8.8/8.4 | 6.1/9.7 | 2.2/2.1 | 19.0/18.3 |
| Dissolved Copper | 36.7/35.5 | 33.9/32.7 | 6.3/6.1 | 5.1/8.3 | 1.9/1.8 | 16.1/15.6 |

Distribution of copper load contribution to the Bay slightly changes when using high range of EMC for park/open land from the Bay Area. Industrial land use contributes approximately 19 percent of the total and dissolved copper load to the Bay. Residential land use contributes approximately 19 and 25 percent of the total and dissolved copper load to the Bay, respectively. Together, commercial and industrial areas are estimated to contribute 24 and 23 percent of the total and dissolved copper, respectively. Park/open land contributes 43 and 40 percent of the total and dissolved copper, respectively. Roads are estimated to contribute approximately 11 and 10 percent of the total and dissolved copper load, respectively.

The significance of contributions from various land uses is different when the model is run for the urbanized portions of the watershed only (Watersheds 1 through 9). Industrial, residential, and commercial runoff contribute a greater proportion of the copper load (approximately three-quarters), while the contribution from parks and open space is lower. Specifically, industrial runoff contributes 35% of total and 34% of dissolved copper (low EMC) and 33% of total and dissolved copper (high EMC); residential runoff contributes 29% of total and 37% of dissolved copper (low EMC) and 28% of total and 36% of dissolved copper (high EMC); and commercial runoff contributes 9% of total and 6% of dissolved copper (low EMC) and 8% of total and 6% of dissolved copper (high EMC). Since the percentage of park and open space land within Watersheds 1 through 9 is only 26%, the copper load from this type of land use is correspondingly smaller—less than 10% of the total and dissolved copper load.

Although these results provide some insight into the major sources of stormwater pollutants, confirmation of some of the basic assumptions of the model are necessary. Open land and agricultural land uses undoubtedly contribute some of the copper. However, insufficient data were available from the study area to assess this contribution. EMC data for the park and open space land uses were provided by Santa Clara Valley Storm Water NPDES Monitoring Program from 1987 through 1994 and San Francisco Bay Area Storm Water Monitoring Program in 1996. EMC data from the FHWA (1990) study also indicate that major roadways may still be a primary source of copper to the Bay.

Table 7 compares estimated EMCs, calculated using the spreadsheet model, with EMCs measured for each storm event at the mass loading stations. Generally, the majority of the estimated EMCs were within one order of magnitude when compared with the measured EMCs. EMCs for copper at the mass loading stations on at Switzer and Chollas Creeks were 29.29 and 28.99 µg/l respectively. Both Switzer and Chollas Creeks are within basin two of the study area with total area of approximately 11,800 acres and total annual runoff volume of approximately 4,600 acre-feet. The total contribution of copper to San Diego Bay from the Switzer and Chollas Creek watersheds is one-fifth of a ton per year compared to approximately one-third of a ton per year estimated from land use stations within the same basin. Mass loading stations results were not used in total copper load calculation to the San Diego Bay to avoid redundancy, however, results from these stations were used to double-check copper loads from land use stations within Watershed 2. Both methods of monitoring, mass loading and land use monitoring, yielded comparable results.

## Copper Loading from Bayside Industries

EMCs used to calculate copper loading from San Diego watersheds were calculated based on flow-weighted composite samples collected from various locations throughout San Diego County. One limitation of the data is that they were collected upstream from the heavily industrialized areas located directly adjacent to San Diego Bay (this was mainly because of difficulties in siting monitoring stations due to tidal influence within the storm drains in the low-lying lands adjacent to the Bay). Consequently, the data did not include runoff from areas suspected to contain elevated concentrations of copper in runoff (e.g., Lindbergh Field, Naval facilities, shipyards). The RWQCB's industrial storm water general permit annual report database was reviewed to determine which facilities had analyzed their runoff for copper. No data on copper were reported for Lindbergh Field or certain shipyards. However, 33 data points for copper were available from the Navy Fleet Industrial Supply Center at Point Loma. The average copper concentration in runoff from this facility was 0.075 mg/l. This value appeared to be within reasonable limits of copper values measured in runoff from other heavy industrial facilities reported in the RWQCB database (although limited data from one shipyard indicated concentrations as high as 0.7 mg/l). Thus, it was selected as a "representative" value and utilized to calculate estimated copper loadings in storm water runoff from the Bayside industries.

Bayside industrial facilities that were included in this calculation included:

- Naval facilities (total of approximately 4,800 acres, including facilities on Point Loma, Naval Air Station, North Island (NASNI), Naval Amphibious Base, and NAVSTA)
- San Diego Airport (Lindbergh Field; approximately 488 acres, based on facility's Notice of Intent to comply with the Industrial Storm Water permit)
- Shipyards and other Bayside industrial facilities (approximately 550 acres)

Assuming that the facilities are completely paved (100% impervious) and assuming an average annual rainfall of 10 inches, this would result in up to 461 kg (1,014 lb) of copper entering San Diego Bay due to runoff from these facilities. This loading value is approximate.

## DRY WEATHER COPPER SOURCES

So-called "dry weather" flows include all water inputs to San Diego Bay that occur during extended dry periods and/or year-round. These may include treated process water and waste water discharges (NPDES permitted discharges), natural river base flows (generally resulting from groundwater infiltration in a gaining stream), reservoir releases (more common during wet-weather, but occasionally lasting into the summer months), and incidental and/or illegal discharges. Each of these categories and its potential significance is discussed below.

### NPDES Permitted Discharges

NPDES process water and waste water discharges are commonly discharged to waters of the United States in many parts of the country. However, in San Diego, the vast majority of these discharges have been eliminated since 1964, with most discharges being routed to the sanitary sewer system with ultimate disposal to the deep ocean outfall 4½ miles offshore in the Pacific Ocean. Some bayside industrial facilities and facilities with permanent dewatering systems that discharges to San Diego Bay still have NPDES permits with associated waste discharge requirements. However, NPDES permitted discharges are not considered a significant source of copper to the Bay.

Storms / year

→ Ave. Volume per year Storm water

Table 7
COMPARISON OF ESTIMATED EMCs WITH MEASURED EMCs AT MASS LOADING STATIONS (µg/l)

| Parameter | SD7-Switzer | | SD8-Chollas | |
|---|---|---|---|---|
| | Estimated EMCs | Measured EMCs | Estimated EMCs | Measured EMCs |
| Total Copper | 28.9 | 28.4 | 28.8 | 39.0 |
| Dissolved Copper | 20.5 | 21.7 | 20.8 | 12.4 |

## Reservoir Releases

The Sweetwater Authority and City of San Diego Department of Water Utilities (both water purveyor members of the San Diego County Water Authority) operate and maintain four water supply reservoirs in the foothills to the east of San Diego Bay: the Loveland and Sweetwater Reservoirs (on the Sweetwater River), and upper and lower Otay Reservoirs (on the Otay River). The Sweetwater Authority adds copper sulfate to control algae growth in the reservoirs. The San Diego Department of Water Utilities curtailed its use of copper sulfate in 1992. In seasons of high rainfall, water agencies release water from the reservoirs, sending water containing potential copper downstream and into San Diego Bay.

The Sweetwater Authority (Robert A. Perdue Water Treatment Plant) adds approximately 16,000 lbs of copper sulfate per year to the Sweetwater Reservoir (annual average, based on 10 years of data; Dennis Bostad, Sweetwater Authority, Pers. Comm.). Assuming that all of this copper sulfate dissolves and does not adsorb to sediments in suspension or at the bottom of the reservoir, this would correspond to 2,895 kg (6,369 lbs) of copper, calculated based on molecular weight. The Sweetwater Authority controls releases from the reservoir system. Releases occur on an irregular schedule; some years there are no releases, while in other years, there are multiple releases. Between 1927 and 1955, there were a total of 49 releases; however, these releases occurred during only 12 calendar years (Dennis Bostad, Sweetwater Authority, Pers. Comm.). For our estimate, we have assumed an average annual release of 6,074 acre-feet/yr. Sweetwater Reservoir has an average capacity of 13,700 acre-feet (average annual capacity since 1980). Using the average annual release volume calculated above, this results in an average annual contribution of copper of 1,274 kg (1,284 lb) to San Diego Bay.

However, a large percentage of this added copper does not go into solution, but rather, adsorbs to sediments. The Sweetwater Authority monitors reservoir water quality, including dissolved copper. Based on copper data obtained between 1985 and 1995, the average dissolved copper concentration was 55 µg/l. Using this concentration, the average annual copper load resulting from reservoir releases would be lower, estimated at 410 kg/year (902 lb/year). The majority of reservoir releases occur in the winter, during the rainy season. Since rainfall and runoff processes tend to disturb bottom sediments and increase turbidity, it is likely that the actual copper loading value lies somewhere between these extremes.

concentration was 55 µg/l. Using this concentration, the average annual copper load resulting

## Natural River Base Flows

The major rivers discharging into San Diego Bay include the Otay River, Sweetwater River, Paleta Creek, Chollas Creek, and Switzer Creek. For the most part, these are intermittent streams that flow in winter when there is sufficient rainfall, runoff, shallow subsurface flow to generate stream flow. Additionally, flows in the Sweetwater and Otay Rivers are controlled by releases from the upland reservoirs (see above). Most of these streams experience tidal influence within ¼ to ½ mile of the Bay. No information is currently available as to the division of groundwater and tidal inflow within these nearshore areas. Further, no information regarding dry season flow (if any) is available. For purposes of this study, natural stream baseflow is not considered to be a major source of water-borne copper to San Diego Bay.

According to data provided by the City of San Diego Department of Water Utilities, dissolved copper concentrations in water from the Otay Reservoirs averaged 7.8 μg/l (based on data collected between 1992 and 1995). Because these data were collected since the Department ceased its use of copper sulfate, they are considered representative of background dissolved copper levels. This natural background concentration of copper is extremely small and likely contributes a negligible amount of copper to San Diego Bay.

## Incidental/Illegal Discharges

Incidental and/or illegal discharges are non-storm water discharges to streams or the storm drain system arising from water usage in the watershed. This may include incidental water uses such as from residential car washing, irrigation, or fire-fighting waters. It may also include illegal discharges, such as improper plumbing connections (e.g., sanitary sewer cross-connections) or illegal dumping/disposal. Some of these discharges potentially include significant concentrations of pollutants, including copper. All of the municipalities surrounding San Diego Bay (i.e., the Cities of San Diego, Chula Vista, Coronado, Imperial Beach, and National City) conduct field screening of dry season discharges to identify potential pollutants and sources.

Typically, these investigations involve conducting field visits to the major outfalls within the city limits. The visits are conducted once or twice a year, generally during the summer months. During the field visits, crews note the presence or absence of dry weather flows, record visual observations, and check for the presence of certain pollutants through the use of colorimetric field test kits that typically have detection limits of 0.01 mg/l and an upper limit of 3.0 or 6.0 mg/l, depending on the test kit. Some cities, such as the City of Chula Vista, estimate the flow rate at the outfall at the time of the visit. Other cities do not estimate the flow rate at all. However, since the visits constitute a single point in time, and since dry weather flows are frequently intermittent (or may occur at night or at times other than when the field visits are conducted), it is not possible to calculate a load on the basis of these investigations. Furthermore, as of this time, there do not appear to be any credible studies available from the published literature that attempt to quantify pollutant loadings from this source (Dr. L. Donald Duke, Assistant Professor, Environmental Science and Engineering Program, U.C.L.A., pers. comm.).

## CONCLUSIONS

A summary of estimated copper loadings from each of the sources discussed in this report is presented in Table 8. Note that loading values are presented as ranges (lowest and highest credible values). Based on the estimates developed in this study, total copper loadings to San Diego Bay from wet and dry weather flows are estimated at between 1,698 and 4,205 kg/year (3,736 - 9,250 lb). This total copper loading consists of approximately 1,288 - 2,471 kg (2,834 - 5,436 lb) from storm water runoff and 410 - 1,734 kg (902 - 3,814 lb) from dry-weather discharges.

In general, the quality of the data used to estimate loadings from storm water runoff is believed to be good, since these estimates were developed based on recent flow-weighted composite samples from watersheds draining into San Diego Bay (or recent data from the San Francisco Bay Area, the geographically nearest and most recent data available on copper in runoff from open space). The quality of estimates for non-storm water discharges is not as high, due to the relative scarcity or complete lack of published data on which to formulate credible estimates. The most significant data gap in this regard is the absence of data on loadings from illicit connections and illegal dumping. It is recommended that future studies should be conducted to quantify loadings from this source. Such studies could include intensive flow and water quality monitoring of dry-weather discharges at outfalls known to have frequent flows. In addition, storm water runoff quality data collected by Bayside industries for compliance with the industrial storm water general permit will serve as an increasingly useful database for estimating loads from industrial facilities along the Bayshore.

Table 8

COPPER LOADING FROM STORMWATER RUNOFF AND DRY WEATHER FLOW

| Source | Low Range (kg) | High Range (kg) | Low Range (lbs) | High Range (lbs) | Comments |
|---|---|---|---|---|---|
| Wet-weather runoff | | | | | |
| Total copper | 1,288 | 2,471 | 2,834 | 5,436 | High range represents total copper load from all watersheds draining into San Diego Bay. Low range assumes only watersheds east of reservoirs on the Sweetwater and Otay Rivers. |
| Dissolved copper | 909 | 1,642 | 1,999 | 3,613 | |
| Bayside industrial storm water runoff | | | | | |
| Airport (Lindbergh field) | >0 | 379 | >0 | 833 | Based on runoff from 488 acres (from industrial general permit NOI). |
| Naval facilities | >0 | 39 | >0 | 85 | Based on runoff from 4,800 acres, including Point Loma, NASNI, Naval Amphibious Base, and NAVSTA. |
| Shipyards/industrial facilities | >0 | 43 | >0 | 96 | Based on runoff from approximately 550 acres. |
| Reservoirs (copper sulfate addition) | | | | | |
| Sweetwater | 410 | 1,273 | 902 | 2,800 | High range assumes that all copper sulfate added to reservoir is released in overflows (probably unrealistically high). Low range value based on water quality monitoring of reservoir waters. No copper sulfate added to Otay since 1992. |
| Otay | 0 | 0 | 0 | 0 | |
| Otay River (copper background levels) | >0 | >0 | >0 | >0 | Amount likely to be extremely small and not significant in total copper loading |
| Illicit connections/illegal dumping | >0 | >0 | >0 | >0 | Not possible to estimate at this time. This is definitely a source of copper, not equal to zero, but at this time, there is no published data or sufficient concentration and flow rate information to develop a meaningful estimate. |
| TOTAL | 1,698 | 4,205 | 3,736 | 9,250 | |

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# APPENDIX A

IEDS

| al | Annual Precip. (inches) |
|---|---|
| 26,053 | 11.50 |
| 20,268 | 11.30 |
| 4,647 | 10.40 |
| 3,832 | 10.80 |
| 4,837 | 11.00 |
| 1,987 | 10.60 |
| 3,483 | 10.60 |
| 29,168 | 12.50 |
| 5,251 | 11.70 |
| 99,526 | |

| |
|---|
| 8,944 |
| 7,755 |
| 2,560 |
| 1,369 |
| 2,438 |
| 802 |
| 1,298 |
| 9,759 |
| 1,917 |
| 36,842 |

it Loads in Pounds

| | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|
| 27 | 86 | 34 | 3 | 0 | 97 | 246 |
| 24 | 59 | 17 | 2 | 0 | 58 | 160 |

it Loads in Pounds

| | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|
| 31 | 59 | 5 | 6 | 0 | 3 | 105 |
| 27 | 41 | 3 | 4 | 0 | 2 | 77 |

t Loads in Pounds

| | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|
| 27 | 113 | 4 | 4 | 2 | 89 | 239 |
| 24 | 78 | 2 | 2 | 1 | 53 | 161 |

t Loads in Pounds

| | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|
| 21 | 30 | 6 | 1 | 0 | 12 | 69 |
| 18 | 21 | 3 | 0 | 0 | 7 | 49 |

t Loads in Pounds

| | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|
| 42 | 35 | 15 | 2 | 0 | 8 | 101 |
| 37 | 24 | 8 | 1 | 0 | 5 | 74 |

t Loads in Pounds

| | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|
| 116 | 271 | 32 | 90 | 44 | 94 | 647 |
| 102 | 188 | 16 | 54 | 26 | 57 | 442 |

t Loads in Pounds

| | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|
| 39 | 56 | 12 | 4 | 10 | 22 | 143 |
| 35 | 39 | 6 | 2 | 6 | 13 | 101 |

r all 9 Basins

| | Ind. | Comm. | Parks/open low | Ag | Roads | Tot. Pounds/yr | Tot. Tons/yr |
|---|---|---|---|---|---|---|---|
| 834 | 977 | 248 | 172 | 63 | 539 | 2,834 | 1.417 |
| 734 | 677 | 125 | 103 | 38 | 323 | 1,999 | 0.999 |

' LOAD FROM EACH LAND USE BASED ON MODEL RESULTS

| | Ind. | Comm. | Parks/open low | Ag | Roads |
|---|---|---|---|---|---|
| % | 14.6% | 4.4% | 26.1% | 9.4% | 4.7% |
| % | 34.5% | 8.8% | 6.1% | 2.2% | 19.0% |
| % | 33.9% | 6.3% | 5.1% | 1.9% | 16.1% |

## NONPOINT SOURCE LOADING SUMMARY FOR 1993/94 THROUGH 1995/96 WET SEASONS - MASS LOADING SITES

DISTRIBUTION OF LAND USE PER BASIN (acres)

| | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Park | Agriculture | Roads | Total | Annual Precip. (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| % Impervious | 0.4 | 0.1 | 0.7 | 0.8 | 0.9 | 0.005 | 0.005 | 0.9 | | |
| Basin | | | | | | | | | | |
| Switzer | 591 | 569 | 274 | 0 | 201 | 509 | 153 | 157 | 2,454 | 10.10 |
| Chollas | 1,391 | 4,420 | 909 | 22 | 879 | 1,264 | 34 | 434 | 9,353 | 11.00 |
| TOTAL | 1,982 | 4,989 | 1,183 | 22 | 1,080 | 1,773 | 187 | 591 | 11,807 | |
| Runoff | | | | | | | | | | |
| Switzer | 249 | 132 | 167 | 0 | 148 | 87 | 26 | 116 | 925 | |
| Chollas | 638 | 1,114 | 604 | 16 | 705 | 236 | 6 | 348 | 3,668 | |

RUNOFF FOR CONSOLIDATED LAND USE CLASSIFICATIONS (acre-feet)

| | Res. | Ind. | Comm. | Park | Ag | Roads | Tot. |
|---|---|---|---|---|---|---|---|
| % Impervious | 18.5% | 70.2% | 90.0% | 0.5% | 0.5% | 90.0% | |
| Switzer | 380 | 167 | 148 | 87 | 26 | 116 | 925 |
| Chollas | 1,752 | 620 | 705 | 236 | 6 | 348 | 3,668 |

CALCULATED AREA-WIDE EMCs FOR 1993/94 THROUGH 1995/95 WET SEASONS

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads |
|---|---|---|---|---|---|---|
| Total Cu | 0.0258 | 0.0347 | 0.0254 | 0.0120 | 0.0120 | 0.0520 |
| Diss. Cu | 0.0227 | 0.0240 | 0.0128 | 0.0072 | 0.0072 | 0.0311 |

| Switzer | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 16 | 10 | 3 | 1 | 16 | 73 | 0.028922 |
| Diss. Cu | 23 | 11 | 5 | 2 | 1 | 10 | 52 | 0.020497 |

| Chollas | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 123 | 58 | 49 | 8 | 0 | 49 | 287 | 0.028799 |
| Diss. Cu | 108 | 40 | 25 | 5 | 0 | 29 | 207 | 0.020789 |

## NONPOINT SOURCE LOADING SUMMARY FOR 1993/94 THROUGH 1995/96 WET SEASONS - 9 SAN DIEGO BAY WATERSHEDS

### DISTRIBUTION OF LAND USE PER BASIN (acres)

| | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Parks | Agriculture | Roads | Total | Annual Precip. (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| % Impervious | 0.4 | 0.1 | 0.7 | 0.8 | 0.9 | 0.005 | 0 | 0.9 | | |
| Basin | | | | | | | | | | |
| 1 | 1,262 | 12,492 | 1,670 | 989 | 1,282 | 6,828 | 875 | 655 | 26,053 | 11.50 |
| 2 | 2,008 | 10,453 | 2,066 | 210 | 1,162 | 2,972 | 229 | 1,168 | 20,268 | 11.30 |
| 3 | 538 | 627 | 1,042 | 366 | 646 | 518 | 5 | 905 | 4,647 | 10.40 |
| 4 | 147 | 1,505 | 967 | | 98 | 1,064 | 21 | 30 | 3,832 | 10.80 |
| 5 | 297 | 1,011 | 1,790 | 9 | 73 | 616 | 256 | 785 | 4,837 | 11.00 |
| 6 | 92 | 1,062 | 493 | | 105 | 126 | | 109 | 1,987 | 10.60 |
| 7 | 285 | 1,962 | 565 | 7 | 284 | 302 | 9 | 69 | 3,483 | 10.60 |
| 8 | 900 | 4,152 | 1,131 | 2,422 | 503 | 12,980 | 6,347 | 733 | 29,168 | 12.50 |
| 9 | 239 | 1,660 | 297 | 488 | 207 | 601 | 1,577 | 182 | 5,251 | 11.70 |
| TOTAL | 5,768 | 34,924 | 10,021 | 4,491 | 4,360 | 26,007 | 9,319 | 4,636 | 99,526 | |

### RUNOFF (acre-feet)

| Basin | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Parks | Agriculture | Roads | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 605 | 3,292 | 1,160 | 758 | 1,075 | 1,333 | 171 | 549 | 8,944 |
| 2 | 945 | 2,707 | 1,410 | 158 | 957 | 570 | 44 | 962 | 7,755 |
| 3 | 233 | 149 | 655 | 254 | 490 | 91 | 1 | 686 | 2,560 |
| 4 | 66 | 372 | 631 | 0 | 77 | 195 | 4 | 24 | 1,369 |
| 5 | 136 | 255 | 1,190 | 7 | 59 | 115 | 48 | 630 | 2,438 |
| 6 | 41 | 258 | 316 | 0 | 81 | 23 | 0 | 84 | 802 |
| 7 | 126 | 477 | 362 | 5 | 220 | 54 | 2 | 53 | 1,298 |
| 8 | 469 | 1,189 | 854 | 2,018 | 458 | 2,755 | 1,347 | 668 | 9,759 |
| 9 | 117 | 445 | 210 | 381 | 177 | 119 | 313 | 155 | 1,917 |
| | | | | | | | | TOTAL | 36,842 |

### RUNOFF FOR CONSOLIDATED LAND USE CLASSIFICATIONS (acre-feet)

| | Residential | Industrial | Commercial | Parks | Agriculture | Roads | Total |
|---|---|---|---|---|---|---|---|
| % Impervious | 0.14 | 0.73 | 0.90 | 0.01 | 0.01 | 0.90 | |
| Basin | | | | | | | |
| 1 | 3,897 | 1,919 | 1,075 | 1,333 | 171 | 549 | 8,944 |
| 2 | 3,652 | 1,569 | 957 | 570 | 44 | 962 | 7,755 |
| 3 | 383 | 908 | 490 | 91 | 1 | 686 | 2,560 |
| 4 | 439 | 631 | 77 | 195 | 4 | 24 | 1,369 |
| 5 | 391 | 1,196 | 59 | 115 | 48 | 630 | 2,438 |
| 6 | 299 | 316 | 81 | 23 | 0 | 84 | 802 |
| 7 | 602 | 367 | 220 | 54 | 2 | 53 | 1,298 |
| 8 | 1,658 | 2,872 | 458 | 2,755 | 1,347 | 668 | 9,759 |
| 9 | 562 | 591 | 177 | 119 | 313 | 155 | 1,917 |
| | | | | | | Total | 36,842 |

### CALCULATED EMCs FOR 1993/94 THROUGH 1995/95 WET SEASONS

| Parameter | Residential | Industrial | Commercial | Parks/open high | Agriculture | Roads | 60% |
|---|---|---|---|---|---|---|---|
| Total Cu | 0.0258 | 0.0347 | 0.0254 | 0.020 | 0.012 | 0.0520 | |
| Diss. Cu | 0.02270 | 0.0240 | 0.0128 | 0.01197 | 0.00718 | 0.03111 | |

| Basin 1 | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 274 | 181 | 74 | 73 | 6 | 78 | 684 |
| Diss. Cu | 241 | 125 | 37 | 43 | 3 | 46 | 496 |

| Basin 2 | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 256 | 148 | 66 | 31 | 1 | 136 | 639 |
| Diss. Cu | 226 | 102 | 33 | 19 | 1 | 81 | 462 |

**Basin 3** — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 86 | 34 | 5 | 0 | 97 | 248 |
| Diss. Cu | 24 | 59 | 17 | 3 | 0 | 58 | 161 |

**Basin 4** — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 31 | 59 | 5 | 11 | 0 | 3 | 110 |
| Diss. Cu | 27 | 41 | 3 | 6 | 0 | 2 | 79 |

**Basin 5** — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 113 | 4 | 6 | 2 | 89 | 241 |
| Diss. Cu | 24 | 78 | 2 | 4 | 1 | 53 | 162 |

**Basin 6** — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 21 | 30 | 6 | 1 | 0 | 12 | 69 |
| Diss. Cu | 18 | 21 | 3 | 1 | 0 | 7 | 50 |

**Basin 7** — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 42 | 35 | 15 | 3 | 0 | 8 | 103 |
| Diss. Cu | 37 | 24 | 8 | 2 | 0 | 5 | 75 |

**Basin 8** — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 116 | 271 | 32 | 150 | 44 | 94 | 707 |
| Diss. Cu | 102 | 188 | 16 | 90 | 26 | 57 | 478 |

**Basin 9** — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 39 | 56 | 12 | 6 | 10 | 22 | 146 |
| Diss. Cu | 35 | 39 | 6 | 4 | 6 | 13 | 103 |

**Total Pollutant Load for all 9 Basins**

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Tot. Pounds/yr | Tot. Tons/yr |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 834 | 977 | 248 | 286 | 63 | 539 | 2,948 | 1.474 |
| Diss. Cu | 734 | 677 | 125 | 171 | 38 | 323 | 2,067 | 1.033 |

**% POLLUTANT LOAD FROM EACH LAND USE BASED ON MODEL RESULTS**

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads |
|---|---|---|---|---|---|---|
| % Land Use | 40.9% | 14.6% | 4.4% | 26.1% | 9.4% | 4.7% |
| Total Cu | 28.3% | 33.2% | 8.4% | 9.7% | 2.1% | 18.3% |
| Diss. Cu | 35.5% | 32.7% | 6.1% | 8.3% | 1.8% | 15.6% |

## NONPOINT SOURCE LOADING SUMMARY FOR 1993/94 THROUGH 1995/96 WET SEASONS - MASS LOADING SITES

### DISTRIBUTION OF LAND USE PER BASIN (acres)

| | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Park | Agriculture | Roads | Total | Annual Precip. (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| % Impervious | 0.4 | 0.1 | 0.7 | 0.8 | 0.9 | 0.005 | 0.005 | 0.9 | | |
| Basin | | | | | | | | | | |
| Switzer | 591 | 569 | 274 | 0 | 201 | 509 | 153 | 157 | 2,454 | 10.10 |
| Chollas | 1,391 | 4,420 | 909 | 22 | 879 | 1,264 | 34 | 434 | 9,353 | 11.00 |
| TOTAL | 1,982 | 4,989 | 1,183 | 22 | 1,080 | 1,773 | 187 | 591 | 11,807 | |
| Runoff | | | | | | | | | | |
| Switzer | 249 | 132 | 167 | 0 | 148 | 87 | 26 | 116 | 925 | |
| Chollas | 638 | 1,114 | 604 | 16 | 705 | 236 | 6 | 348 | 3,668 | |

### RUNOFF FOR CONSOLIDATED LAND USE CLASSIFICATIONS (acre-feet)

| | Res. | Ind. | Comm. | Park | Ag | Roads | Tot. |
|---|---|---|---|---|---|---|---|
| % Impervious | 18.5% | 70.2% | 90.0% | 0.5% | 0.5% | 90.0% | |
| Switzer | 380 | 167 | 148 | 87 | 26 | 116 | 925 |
| Chollas | 1,752 | 620 | 705 | 236 | 6 | 348 | 3,668 |

### CALCULATED AREA-WIDE EMCs FOR 1993/94 THROUGH 1995/95 WET SEASONS

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads |
|---|---|---|---|---|---|---|
| Total Cu | 0.0258 | 0.0347 | 0.0254 | 0.0200 | 0.0120 | 0.0520 |
| Diss. Cu | 0.0227 | 0.0240 | 0.0128 | 0.0120 | 0.0072 | 0.0311 |

| Switzer | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 16 | 10 | 5 | 1 | 16 | 75 | 0.029677 |
| Diss. Cu | 23 | 11 | 5 | 3 | 1 | 10 | 53 | 0.020948 |

| Chollas | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 123 | 58 | 49 | 13 | 0 | 49 | 292 | 0.029314 |
| Diss. Cu | 108 | 40 | 25 | 8 | 0 | 29 | 210 | 0.021097 |

# NONPOINT SOURCE COPPER LOADING SUMMARY FOR SAN DIEGO BAY TMDL STUDY - LAND USE SITES

DISTRIBUTION OF LAND USE PER BASIN (acres)

| | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Commercial | Parks/open space | Agriculture | Roads | Total | Annual Precip. (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| % Impervious | 0.4 | 0.1 | 0.7 | 0.8 | 0.9 | 0.005 | 0.005 | 0.9 | | |
| Basin | | | | | | | | | | |
| 1 | 1,262 | 12,492 | 1,670 | 989 | 1,282 | 6,828 | 875 | 655 | 26,053 | 11.50 |
| 2 | 2,008 | 10,453 | 2,066 | 210 | 1,162 | 2,972 | 229 | 1,168 | 20,268 | 11.30 |
| 3 | 538 | 627 | 1,042 | 366 | 646 | 518 | 5 | 905 | 4,647 | 10.40 |
| 4 | 147 | 1,505 | 967 | | 98 | 1,064 | 21 | 30 | 3,832 | 10.80 |
| 5 | 297 | 1,011 | 1,790 | 9 | 73 | 616 | 256 | 785 | 4,837 | 11.00 |
| 6 | 92 | 1,062 | 493 | | 105 | 126 | | 109 | 1,987 | 10.60 |
| 7 | 285 | 1,962 | 565 | 7 | 284 | 302 | 9 | 69 | 3,483 | 10.60 |
| 8 | 900 | 4,152 | 1,131 | 2,422 | 503 | 12,980 | 6,347 | 733 | 29,168 | 12.50 |
| 9 | 239 | 1,660 | 297 | 488 | 207 | 601 | 1,577 | 182 | 5,251 | 11.70 |
| 10 | 0 | 9,175 | 436 | 0 | 505 | 159,547 | 9,139 | 532 | 179,334 | 14.00 |
| TOTAL | 5,768 | 44,099 | 10,457 | 4,491 | 4,865 | 185,554 | 18,458 | 5,168 | 278,860 | |

RUNOFF (acre-feet)

| Basin | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Commercial | Parks/open space | Agriculture | Roads | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 605 | 3,292 | 1,160 | 758 | 1,075 | 1,333 | 171 | 549 | 8,944 |
| 2 | 945 | 2,707 | 1,410 | 158 | 957 | 570 | 44 | 962 | 7,755 |
| 3 | 233 | 149 | 655 | 254 | 490 | 91 | 1 | 686 | 2,560 |
| 4 | 66 | 372 | 631 | 0 | 77 | 195 | 4 | 24 | 1,369 |
| 5 | 136 | 255 | 1,190 | 7 | 59 | 115 | 48 | 630 | 2,438 |
| 6 | 41 | 258 | 316 | 0 | 81 | 23 | 0 | 84 | 802 |
| 7 | 126 | 477 | 362 | 5 | 220 | 54 | 2 | 53 | 1,298 |
| 8 | 469 | 1,189 | 854 | 2,018 | 458 | 2,755 | 1,347 | 668 | 9,759 |
| 9 | 117 | 445 | 210 | 381 | 177 | 119 | 313 | 155 | 1,917 |
| 10 | 0 | 2,944 | 369 | 0 | 516 | 37,926 | 2,172 | 543 | 44,469 |
| TOTAL | | | | | | | | | 81,311 |

RUNOFF FOR CONSOLIDATED LAND USE CLASSIFICATIONS (acre-feet)

| | Residential | Industrial | Commercial | Parks/open low | Agriculture | Roads | Total |
|---|---|---|---|---|---|---|---|
| % Impervious | 0.13 | 0.73 | 0.90 | 0.005 | 0.005 | 0.90 | |
| Basin | | | | | | | |
| 1 | 3,897 | 1,919 | 1,075 | 1,333 | 171 | 549 | 8,944 |
| 2 | 3,652 | 1,569 | 957 | 570 | 44 | 962 | 7,755 |
| 3 | 383 | 908 | 490 | 91 | 1 | 686 | 2,560 |
| 4 | 439 | 631 | 77 | 195 | 4 | 24 | 1,369 |
| 5 | 391 | 1,196 | 59 | 115 | 48 | 630 | 2,438 |
| 6 | 299 | 316 | 81 | 23 | 0 | 84 | 802 |
| 7 | 602 | 367 | 220 | 54 | 2 | 53 | 1,298 |
| 8 | 1,658 | 2,872 | 458 | 2,755 | 1,347 | 668 | 9,759 |
| 9 | 562 | 591 | 177 | 119 | 313 | 155 | 1,917 |
| 10 | 2,944 | 369 | 516 | 37,926 | 2,172 | 543 | 44,469 |
| | | | | | | Total | 81,311 |

CALCULATED EMCs FOR 1993/94 THROUGH 1995/95 WET SEASONS

| Parameter | Residential | Industrial | Commercial | Parks/open high | Agriculture | Roads |
|---|---|---|---|---|---|---|
| Total Cu | 0.0258 | 0.0347 | 0.0254 | 0.020 | 0.012 | 0.0520 |
| Diss. Cu | 0.02270 | 0.0240 | 0.0128 | 0.01197 | 0.00718 | 0.03111 |

Basin 1 — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| | | | | | | | 60% |
| Total Cu | 274 | 181 | 74 | 73 | 6 | 78 | 684 |
| Diss. Cu | 241 | 125 | 37 | 43 | 3 | 46 | 496 |

Basin 2 — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 256 | 148 | 66 | 31 | 1 | 136 | 639 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Diss. Cu | 226 | 102 | 33 | 19 | 1 | 81 | 462 |

**Basin 3** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 86 | 34 | 5 | 0 | 97 | 248 |
| Diss. Cu | 24 | 59 | 17 | 3 | 0 | 58 | 161 |

**Basin 4** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 31 | 59 | 5 | 11 | 0 | 3 | 110 |
| Diss. Cu | 27 | 41 | 3 | 6 | 0 | 2 | 79 |

**Basin 5** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 113 | 4 | 6 | 2 | 89 | 241 |
| Diss. Cu | 24 | 78 | 2 | 4 | 1 | 53 | 162 |

**Basin 6** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 21 | 30 | 6 | 1 | 0 | 12 | 69 |
| Diss. Cu | 18 | 21 | 3 | 1 | 0 | 7 | 50 |

**Basin 7** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 42 | 35 | 15 | 3 | 0 | 8 | 103 |
| Diss. Cu | 37 | 24 | 8 | 2 | 0 | 5 | 75 |

**Basin 8** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 116 | 271 | 32 | 150 | 44 | 94 | 707 |
| Diss. Cu | 102 | 188 | 16 | 90 | 26 | 57 | 478 |

**Basin 9** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 39 | 56 | 12 | 6 | 10 | 22 | 146 |
| Diss. Cu | 35 | 39 | 6 | 4 | 6 | 13 | 103 |

**Basin 10** Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 207 | 35 | 36 | 2,063 | 71 | 77 | 2,488 |
| Diss. Cu | 182 | 24 | 18 | 1,234 | 42 | 46 | 1,547 |

**Total Pollutant Load for all 10 Basins**

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Tot. Pounds/yr | Tot. Tons/yr |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 1,041 | 1,012 | 284 | 2,349 | 134 | 616 | 5,436 | 2.718 |
| Diss. Cu | 915 | 701 | 143 | 1,405 | 80 | 369 | 3,613 | 1.807 |

**% POLLUTANT LOAD FROM EACH LAND USE BASED ON MODEL RESULTS**

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads |
|---|---|---|---|---|---|---|
| % Land Use | 17.9% | 5.4% | 1.7% | 66.5% | 6.6% | 1.9% |
| Total Cu | 19.1% | 18.6% | 5.2% | 43.2% | 2.5% | 11.3% |
| Diss. Cu | 25.3% | 19.4% | 4.0% | 38.9% | 2.2% | 10.2% |

NONPOINT SOURCE COPPER LOADING SUMMARY FOR SAN DIEGO BAY TMDL STUDY - MASS LOADING SITES

DISTRIBUTION OF LAND USE PER BASIN (acres)

| | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Parks/open high | Agriculture | Roads | Total | Annual Precip. (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| % Impervious | 0.4 | 0.1 | 0.7 | 0.8 | 0.9 | 0.005 | 0.005 | 0.9 | | |
| Basin | | | | | | | | | | |
| Switzer | 591 | 569 | 274 | 0 | 201 | 509 | 153 | 157 | 2,454 | 10.10 |
| Chollas | 1,391 | 4,420 | 909 | 22 | 879 | 1,264 | 34 | 434 | 9,353 | 11.00 |
| TOTAL | 1,982 | 4,989 | 1,183 | 22 | 1,080 | 1,773 | 187 | 591 | 11,807 | |
| Runoff | | | | | | | | | | |
| Switzer | 249 | 132 | 167 | 0 | 148 | 87 | 26 | 116 | 925 | |
| Chollas | 638 | 1,114 | 604 | 16 | 705 | 236 | 6 | 348 | 3,668 | |

RUNOFF FOR CONSOLIDATED LAND USE CLASSIFICATIONS (acre-feet)

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Tot. |
|---|---|---|---|---|---|---|---|
| % Impervious | 18.5% | 70.2% | 90.0% | 0.5% | 0.5% | 90.0% | |
| Switzer | 380 | 167 | 148 | 87 | 26 | 116 | 925 |
| Chollas | 1,752 | 620 | 705 | 236 | 6 | 348 | 3,668 |

CALCULATED AREA-WIDE EMCs FOR 1993/94 THROUGH 1995/95 WET SEASONS

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads |
|---|---|---|---|---|---|---|
| Total Cu | 0.0258 | 0.0347 | 0.0254 | 0.0200 | 0.0120 | 0.0520 |
| Diss. Cu | 0.0227 | 0.0240 | 0.0128 | 0.0120 | 0.0072 | 0.0311 |

Switzer — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 16 | 10 | 5 | 1 | 16 | 75 | 0.029677 |
| Diss. Cu | 23 | 11 | 5 | 3 | 1 | 10 | 53 | 0.020948 |

Chollas — Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 123 | 58 | 49 | 13 | 0 | 49 | 292 | 0.029314 |
| Diss. Cu | 108 | 40 | 25 | 8 | 0 | 29 | 210 | 0.021097 |

## NONPOINT SOURCE COPPER LOADING SUMMARY FOR SAN DIEGO BAY TMDL STUDY - LAND USE SITES

### DISTRIBUTION OF LAND USE PER BASIN (acres)

| | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Parks/open space | Agriculture | Roads | Total | Annual Precip. (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| % Impervious | 0.4 | 0.1 | 0.7 | 0.8 | 0.9 | 0.005 | 0.005 | 0.9 | | |
| Basin | | | | | | | | | | |
| 1 | 1,262 | 12,492 | 1,670 | 989 | 1,282 | 6,828 | 875 | 655 | 26,053 | 11.50 |
| 2 | 2,008 | 10,453 | 2,066 | 210 | 1,162 | 2,972 | 229 | 1,168 | 20,268 | 11.30 |
| 3 | 538 | 627 | 1,042 | 366 | 646 | 518 | 5 | 905 | 4,647 | 10.40 |
| 4 | 147 | 1,505 | 967 | | 98 | 1,064 | 21 | 30 | 3,832 | 10.80 |
| 5 | 297 | 1,011 | 1,790 | 9 | 73 | 616 | 256 | 785 | 4,837 | 11.00 |
| 6 | 92 | 1,062 | 493 | | 105 | 126 | | 109 | 1,987 | 10.60 |
| 7 | 285 | 1,962 | 565 | 7 | 284 | 302 | 9 | 69 | 3,483 | 10.60 |
| 8 | 900 | 4,152 | 1,131 | 2,422 | 503 | 12,980 | 6,347 | 733 | 29,168 | 12.50 |
| 9 | 239 | 1,660 | 297 | 488 | 207 | 601 | 1,577 | 182 | 5,251 | 11.70 |
| 10 | 0 | 9,175 | 436 | 0 | 505 | 159,547 | 9,139 | 532 | 179,334 | 14.00 |
| TOTAL | 5,768 | 44,099 | 10,457 | 4,491 | 4,865 | 185,554 | 18,458 | 5,168 | 278,860 | |

### RUNOFF (acre-feet)

| Basin | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Parks/open space | Agriculture | Roads | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 605 | 3,292 | 1,160 | 758 | 1,075 | 1,333 | 171 | 549 | 8,944 |
| 2 | 945 | 2,707 | 1,410 | 158 | 957 | 570 | 44 | 962 | 7,755 |
| 3 | 233 | 149 | 655 | 254 | 490 | 91 | 1 | 686 | 2,560 |
| 4 | 66 | 372 | 631 | 0 | 77 | 195 | 4 | 24 | 1,369 |
| 5 | 136 | 255 | 1,190 | 7 | 59 | 115 | 48 | 630 | 2,438 |
| 6 | 41 | 258 | 316 | 0 | 81 | 23 | 0 | 84 | 802 |
| 7 | 126 | 477 | 362 | 5 | 220 | 54 | 2 | 53 | 1,298 |
| 8 | 469 | 1,189 | 854 | 2,018 | 458 | 2,755 | 1,347 | 668 | 9,759 |
| 9 | 117 | 445 | 210 | 381 | 177 | 119 | 313 | 155 | 1,917 |
| 10 | 0 | 2,944 | 369 | 0 | 516 | 37,926 | 2,172 | 543 | 44,469 |
| | | | | | | | | TOTAL | 81,311 |

### RUNOFF FOR CONSOLIDATED LAND USE CLASSIFICATIONS (acre-feet)

| | Residential | Industrial | Commercial | Parks/open low | Agriculture | Roads | Total |
|---|---|---|---|---|---|---|---|
| % Impervious | 0.13 | 0.73 | 0.90 | 0.005 | 0.005 | 0.90 | |
| Basin | | | | | | | |
| 1 | 3,897 | 1,919 | 1,075 | 1,333 | 171 | 549 | 8,944 |
| 2 | 3,652 | 1,569 | 957 | 570 | 44 | 962 | 7,755 |
| 3 | 383 | 908 | 490 | 91 | 1 | 686 | 2,560 |
| 4 | 439 | 631 | 77 | 195 | 4 | 24 | 1,369 |
| 5 | 391 | 1,196 | 59 | 115 | 48 | 630 | 2,438 |
| 6 | 299 | 316 | 81 | 23 | 0 | 84 | 802 |
| 7 | 602 | 367 | 220 | 54 | 2 | 53 | 1,298 |
| 8 | 1,658 | 2,872 | 458 | 2,755 | 1,347 | 668 | 9,759 |
| 9 | 562 | 591 | 177 | 119 | 313 | 155 | 1,917 |
| 10 | 2,944 | 369 | 516 | 37,926 | 2,172 | 543 | 44,469 |
| | | | | | | Total | 81,311 |

### CALCULATED EMCs FOR 1993/94 THROUGH 1995/95 WET SEASONS

| Parameter | Residential | Industrial | Commercial | Parks/open low | Agriculture | Roads | |
|---|---|---|---|---|---|---|---|
| Total Cu | 0.0258 | 0.0347 | 0.0254 | 0.012 | 0.012 | 0.0520 | 60% |
| Diss. Cu | 0.02270 | 0.0240 | 0.0128 | 0.00718 | 0.00718 | 0.03111 | |

| Basin 1 | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 274 | 181 | 74 | 44 | 6 | 78 | 655 |
| Diss. Cu | 241 | 125 | 37 | 26 | 3 | 46 | 479 |

| Basin 2 | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 256 | 148 | 66 | 19 | 1 | 136 | 627 |

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Diss. Cu | 226 | 102 | 33 | 11 | 1 | 81 | 455 |

Basin 3 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 86 | 34 | 3 | 0 | 97 | 246 |
| Diss. Cu | 24 | 59 | 17 | 2 | 0 | 58 | 160 |

Basin 4 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 31 | 59 | 5 | 6 | 0 | 3 | 105 |
| Diss. Cu | 27 | 41 | 3 | 4 | 0 | 2 | 77 |

Basin 5 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 113 | 4 | 4 | 2 | 89 | 239 |
| Diss. Cu | 24 | 78 | 2 | 2 | 1 | 53 | 161 |

Basin 6 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 21 | 30 | 6 | 1 | 0 | 12 | 69 |
| Diss. Cu | 18 | 21 | 3 | 0 | 0 | 7 | 49 |

Basin 7 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 42 | 35 | 15 | 2 | 0 | 8 | 101 |
| Diss. Cu | 37 | 24 | 8 | 1 | 0 | 5 | 74 |

Basin 8 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 116 | 271 | 32 | 90 | 44 | 94 | 647 |
| Diss. Cu | 102 | 188 | 16 | 54 | 26 | 57 | 442 |

Basin 9 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 39 | 56 | 12 | 4 | 10 | 22 | 143 |
| Diss. Cu | 35 | 39 | 6 | 2 | 6 | 13 | 101 |

Basin 10 Pollutant Loads in Pounds

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Total |
|---|---|---|---|---|---|---|---|
| Total Cu | 207 | 35 | 36 | 1,238 | 71 | 77 | 1,663 |
| Diss. Cu | 182 | 24 | 18 | 741 | 42 | 46 | 1,053 |

Total Pollutant Load for all 10 Basins

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads | Tot. Pounds/yr | Tot. Tons/yr |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 1,041 | 1,012 | 284 | 1,409 | 134 | 616 | 4,496 | 2.248 |
| Diss. Cu | 915 | 701 | 143 | 843 | 80 | 369 | 3,051 | 1.526 |

% POLLUTANT LOAD FROM EACH LAND USE BASED ON MODEL RESULTS

| | Res. | Ind. | Comm. | Parks/open low | Ag | Roads |
|---|---|---|---|---|---|---|
| % Land Use | 17.9% | 5.4% | 1.7% | 66.5% | 6.6% | 1.9% |
| Total Cu | 23.1% | 22.5% | 6.3% | 31.3% | 3.0% | 13.7% |
| Diss. Cu | 30.0% | 23.0% | 4.7% | 27.6% | 2.6% | 12.1% |

NONPOINT SOURCE COPPER LOADING SUMMARY FOR SAN DIEGO BAY TMDL STUDY - MASS LOADING SITES

DISTRIBUTION OF LAND USE PER BASIN (acres)

| | Multi-Family Residential | Single Family Residential | Light Industry | Heavy Industry | Comm-ercial | Parks/open high | Agriculture | Roads | Total | Annual Precip. (inches) |
|---|---|---|---|---|---|---|---|---|---|---|
| % Impervious | 0.4 | 0.1 | 0.7 | 0.8 | 0.9 | 0.005 | 0.005 | 0.9 | | |
| Basin | | | | | | | | | | |
| Switzer | 591 | 569 | 274 | 0 | 201 | 509 | 153 | 157 | 2,454 | 10.10 |
| Chollas | 1,391 | 4,420 | 909 | 22 | 879 | 1,264 | 34 | 434 | 9,353 | 11.00 |
| TOTAL | 1,982 | 4,989 | 1,183 | 22 | 1,080 | 1,773 | 187 | 591 | 11,807 | |
| Runoff | | | | | | | | | | |
| Switzer | 249 | 132 | 167 | 0 | 148 | 87 | 26 | 116 | 925 | |
| Chollas | 638 | 1,114 | 604 | 16 | 705 | 236 | 6 | 348 | 3,668 | |

RUNOFF FOR CONSOLIDATED LAND USE CLASSIFICATIONS (acre-feet)

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Tot. |
|---|---|---|---|---|---|---|---|
| % Impervious | 18.5% | 70.2% | 90.0% | 0.5% | 0.5% | 90.0% | |
| Switzer | 380 | 167 | 148 | 87 | 26 | 116 | 925 |
| Chollas | 1,752 | 620 | 705 | 236 | 6 | 348 | 3,668 |

CALCULATED AREA-WIDE EMCs FOR 1993/94 THROUGH 1995/95 WET SEASONS

| | Res. | Ind. | Comm. | Parks/open high | Ag | Roads |
|---|---|---|---|---|---|---|
| Total Cu | 0.0258 | 0.0347 | 0.0254 | 0.0200 | 0.0120 | 0.0520 |
| Diss. Cu | 0.0227 | 0.0240 | 0.0128 | 0.0120 | 0.0072 | 0.0311 |

| Switzer | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 27 | 16 | 10 | 5 | 1 | 16 | 75 | 0.029677 |
| Diss. Cu | 23 | 11 | 5 | 3 | 1 | 10 | 53 | 0.020948 |

| Chollas | Pollutant Loads in Pounds Res. | Ind. | Comm. | Parks/open high | Ag | Roads | Total | Estimated EMC |
|---|---|---|---|---|---|---|---|---|
| Total Cu | 123 | 58 | 49 | 13 | 0 | 49 | 292 | 0.029314 |
| Diss. Cu | 108 | 40 | 25 | 8 | 0 | 29 | 210 | 0.021097 |

# APPENDIX B
# POINT SOURCE CALCULATIONS

RECEIVED
FEB 15 1996
PORT OF SAN DIEGO
ENVIRONMENTAL MANAGEMENT

# SAN DIEGO UNIFIED PORT DISTRICT
## HARBOR POLICE
## 1995
## YACHT CLUB/MARINA/BOAT YARD/ANCHORAGE ANNUAL SURVEY

(A) Slips or Buoys
(B) Number occupied or anchored
(C) Number of vessels involved with live-aboard.
(D) Number of live-aboard.
(E) Pump-Out station.
(F) Shower or Bath facilities.

| | (A) | (B) | (C) | (D) | (E) | (F) |
|---|---|---|---|---|---|---|
| SHELTER ISLAND | | | | | | |
| La Playa Yacht Club | 004 | 000 | 000 | 000 | NO | NO |
| La Playa Cove Anchorage A-1 | 000 | 000 | 000 | 000 | NO | NO |
| Shelter Island (Bay-side) | 000 | 000 | 000 | 000 | NO | NO |
| Shelter Island Roadstead A-1a,b,c | 044 | 044 | 014 | 000 | NO | NO |
| Bay Club Marina | 154 | 150 | 014 | 022 | NO | YES |
| Crow's Nest Yacht Brokerage | 025 | 022 | 000 | 000 | NO | NO |
| Gold Coast Anchorage | 035 | 021 | 002 | 002 | NO | YES |
| Half Moon Anchorage | 180 | 170 | 019 | 027 | NO | YES |
| Harbor Police Transient Facility | 031 | 016 | 008 | 000 | YES | NO |
| Kona Kai Club | 516 | 485 | 010 | 038 | NO | YES |
| Pearsons Marine Service | 000 | 000 | 000 | 000 | YES | NO |
| San Diego Marlin Club | 006 | 000 | 000 | 000 | NO | NO |
| San Diego Yacht Club | 578 | 578 | 015 | 017 | NO | YES |
| Shelter Island Inn Marina | 190 | 170 | 020 | 030 | NO | YES |
| Silver Gate Yacht Club | 144 | 144 | 030 | 040 | NO | YES |
| Southwestern Yacht Club | 385 | 385 | 020 | 040 | NO | YES |
| Shelter Island Boatyard | 036 | 034 | 007 | 012 | NO | YES |
| Σ | 2219 | | | | | |
| AMERICA'S CUP HARBOR | | | | | | |
| Anchorage Area A-2 | 170 | 163 | 052 | 000 | NO | NO |
| Admiralty Marine (S.D.Marine Exch) | 003 | 002 | 000 | 000 | NO | NO |
| Bali Hai Restaurant | Restaurant Guest Dock Only | | | | | |
| Driscoll's Inc. | 050 | 020 | 000 | 000 | NO | YES |
| Endurance Marine\Eichenlaub's | 013 | 013 | 002 | 002 | NO | YES |
| Fisherman's Landing | 020 | 016 | 000 | 000 | NO | NO |
| Fisherman's Village | 125 | 066 | 010 | 015 | NO | YES |
| H & M Landing | 030 | 022 | 006 | 012 | NO | YES |
| Koehler Kraft Co. | 030 | 030 | 001 | 001 | NO | NO |
| Nielsen / Beaumont | 020 | 020 | 001 | 002 | NO | YES |
| Point Loma Sportfishers Assn. | 030 | 023 | 003 | 007 | NO | NO |
| Red Sails Inn | 012 | 012 | 000 | 000 | NO | NO |
| Shelter Cove Marina | 161 | 108 | 024 | 033 | NO | YES |
| Shelter Island Boatyard | 036 | 034 | 007 | 014 | NO | YES |
| Sun Harbor Marina | 120 | 110 | 014 | 020 | NO | YES |

| | | | | | | |
|---|---|---|---|---|---|---|
| HARBOR ISLAND | | | | | | |
| Cabrillo Isle Marina | 420 | 320 | 035 | 044 | NO | YES |
| Cortez Fuel Dock | 002 | 002 | 000 | 000 | YES | YES |
| Convair Sailing Club | 012 | 012 | 000 | 000 | NO | NO |
| Harbor Island West Marina | 620 | 520 | 063 | 100 | YES | YES |
| Harbor Island West Fuel Dock | 002 | 002 | 002 | 003 | YES | YES |
| Marina Cortez | 520 | 490 | 031 | 044 | YES | YES |
| MCRD Boathouse/Marina | 060 | 060 | 000 | 000 | NO | YES |
| NTC Aquatic Sports Center/Marina | 084 | 064 | 000 | 000 | NO | YES |
| Sheraton East Hotel Marina | 042 | 042 | 003 | 006 | YES | YES |
| Sunroad Resort Marina | 610 | 520 | 100 | 250 | YES | YES |
| Tom Ham's Lighthouse Restaurant | 002 | 000 | 000 | 000 | NO | NO |
| EMBARCADERO | | | | | | |
| Laurel St Roadstead Anchorage A-3 | 142 | 136 | 039 | 052 | NO | NO |
| Vicinity of Coast Guard Station | 015 | 015 | 015 | 008 | NO | NO |
| Grape St. Pier North | Not Occupied | | | | | |
| Grape St. Pier South | Not Occupied | | | | | |
| Grape St. Fuel Pier | Not Occupied | | | | | |
| G St Mole | 127 | 070 | 005 | 007 | NO | NO |
| Marriott Hotel Marina | 446 | 390 | 000 | 000 | NO | YES |
| Chart House Restaurant | 002 | Used during open hours | | | | |
| Anthony's | 002 | Used during open hours | | | | |
| CORONADO | | | | | | |
| Coronado Landing | 013 | Varies | | 000 | NO | NO |
| Coronado Roadstead Anchorage A-4 | 069 | 062 | 017 | 029 | NO | NO |
| Coronado Anchorage A-5 | 007 | 007 | 004 | 006 | NO | NO |
| Coronado Cays Marina | 056 | 048 | 005 | 008 | NO | YES |
| Coronado Cays Yacht Club | 008 | 000 | 000 | 000 | NO | YES |
| Coronado Yacht Club | 260 | 250 | 026 | 046 | NO | YES |
| Crown Cove | 000 | 000 | 000 | 000 | NO | YES |
| Glorietta Bay Marina | 105 | 073 | 002 | 002 | YES | YES |
| Glorietta Bay Golf Course | 014 | 014 | 014 | 006 | NO | NO |
| Loews Resort Marina | 080 | 075 | 008 | 015 | YES | YES |
| NAB Fiddler's Cove Marina Area A-6 | | | | | | |
| (Slips) | 266 | 233 | 034 | 080 | YES | YES |
| (Mooring Balls) | 148 | 100 | 000 | 000 | NO | NO |
| Σ | | 562 | | | | |
| NATIONAL CITY | | | | | | |
| Anchorage Area A-8 | 150 | 150 | 055 | 063 | NO | NO |
| CHULA VISTA | | | | | | |
| Chula Vista Marina | 552 | 442 | 055 | 055 | YES | YES |
| California Yacht Marina | 340 | 275 | 050 | 098 | YES | YES |
| South Bay Boat Yard | 035 | 035 | 000 | 000 | NO | YES |
| South San Diego Bay | No anchoring permitted | | | | | |
| Totals | 8,281 | 7,165 | 885 | 1,272 | 14 | 37 |

This list was compiled from, telephone calls, and visual observations and is current through November 4, 1995.

Summary:

The 1995 vessel count shows a general decrease in the area of anchored vessels by 313. A decrease in the number of anchored vessels is due to the Bay Wide Anchoring Plan of June 1, 1995.

The following reported the availability of sewage pump-outs:

Harbor Police Float Shelter Island
Kona Kai Marina
Pearson's Marine Service
Cortez Fuel Dock
Harbor Island West Marina
Harbor Island West Fuel Dock
Marina Cortez
Sheraton East Hotel Marina
Sunroad Resort Marina
Glorietta Bay Marina
NAB Fiddler's Cove Marina
Loews Resort Marina
Chula Vista Marina
California Yacht Marina

New pump-outs:
Chula Vista Ramp
National City Ramp

The major change in anchorages:

Vessels entering San Diego Bay need to request a permit to anchor. There is no fee for permit. Persons requesting a permit can do so by calling on their radio or stopping at the Harbor Police Dock on Shelter Island, or by calling 686-6272.

## APPENDIX B
## COPPER LOADING TO SAN DIEGO BAY
## ESTIMATES OF ANNUAL DISCHARGES OF COPPER FROM SHIP AND BOAT YARDS

| Sample Point | May 31, 1996 Result (mg/kg) | Background at Storm Drain (mg/kg) | Total Estimated Area of Ship Yard (sq m) | Sample Thickness (m) | Dry Weight Sediment Density (kg/cu m) | Number of Years Represented by Sample |
|---|---|---|---|---|---|---|
| NSS-01 | 360 | | | | | |
| NSS-02 | 84 | | | | | |
| NSS-03 | 390 | | | | | |
| NSS-04 | 630 | | | | | |
| NSS-05 | 400 | | | | | |
| NSS-06 | 380 | | | | | |
| NSS-07 | 590 | | | | | |
| NSS-08 | 530 | | | | | |
| NSS-09 | 390 | | | | | |
| NSS-10 | 880 | | | | | |
| NSS-11 | 450 | | | | | |
| NSS-12 | 890 | | | | | |
| NSS-13 | 980 | | | | | |
| NSS-14 | 220 | | | | | |
| NSS-15 | 1300 | | | | | |
| | | | | | | |
| **Average** | **565** | 23 | 152933 | 0.020 | 1300 | 3 |
| | | | | | **Total Annual Copper From NASSCO (kg)** | **718** |

# APPENDIX B
## COPPER LOADING TO SAN DIEGO BAY
## ESTIMATES OF ANNUAL DISCHARGES OF COPPER FROM SHIP AND BOAT YARDS

| Sample Point | May 31, 1996 Result (mg/kg) | Background at Storm Drain (mg/kg) | Total Estimated Area of Ship Yard (sq m) | Sample Thickness (m) | Dry Weight Sediment Density (kg/cu m) | Number of Years Represented by Sample |
|---|---|---|---|---|---|---|
| SWM-01 | 2500 | | | | | |
| SWM-02 | 380 | | | | | |
| SWM-03 | 260 | | | | | |
| SWM-04 | 1900 | | | | | |
| SWM-05 | 310 | | | | | |
| SWM-06 | 510 | | | | | |
| SWM-07 | 1700 | | | | | |
| SWM-08 | 1200 | | | | | |
| SWM-09 | 250 | | | | | |
| SWM-10 | 280 | | | | | |
| SWM-11 | 370 | | | | | |
| SWM-12 | 520 | | | | | |
| SWM-13 | 180 | | | | | |
| SWM-14 | 940 | | | | | |
| SWM-15 | 610 | | | | | |
| Average | 794 | 190 | 67648 | 0.020 | 1300 | 3 |
| | | | | | Total Annual Copper From Southwest Marine (kg) | 354 |

APPENDIX B
COPPER LOADING TO SAN DIEGO BAY
ESTIMATES OF ANNUAL DISCHARGES OF COPPER FROM SHIP AND BOAT YARDS

| Sample Point | May 30, 1996 Result (mg/kg) | Background at Storm Drain (mg/kg) | Total Estimated Area of Ship Yard (sq m) | Sample Thickness (m) | Dry Weight Sediment Density (kg/cu m) | Number of Years Represented by Sample |
|---|---|---|---|---|---|---|
| CNM-01 | 170 | | | | | |
| CNM-02 | 170 | | | | | |
| CNM-03 | 260 | | | | | |
| CNM-04 | 80 | | | | | |
| CNM-05 | 160 | | | | | |
| CNM-06 | 200 | | | | | |
| CNM-07 | 100 | | | | | |
| CNM-08 | 620 | | | | | |
| CNM-09 | 250 | | | | | |
| CNM-10 | 180 | | | | | |
| | | | | | | |
| Average | 219 | 3.1 | 66346 | 0.020 | 1300 | 3 |
| | | | | | Total Annual Copper From Continental Maritime (kg) | 124 |

## APPENDIX B
## COPPER LOADING TO SAN DIEGO BAY
## ESTIMATES OF ANNUAL DISCHARGES OF COPPER FROM SHIP AND BOAT YARDS

| Sample Point | March 5, 1996 Result (mg/kg) | Average Background at Storm Drains (mg/kg) | Total Estimated Area of Ship Yard (sq m) | Sample Thickness (m) | Dry Weight Sediment Density (kg/cu m) | Number of Years Represented by Sample |
|---|---|---|---|---|---|---|
| CMB-01 | 1100 | | | | | |
| CMB-02 | 550 | | | | | |
| CMB-03 | 990 | | | | | |
| CMB-04 | 1000 | | | | | |
| CMB-05 | 780 | | | | | |
| CMB-06 | 350 | | | | | |
| CMB-07 | 2500 | | | | | |
| CMB-08 | 340 | | | | | |
| CMB-09 | 160 | | | | | |
| CMB-10 | 300 | | | | | |
| CMB-11 | 1400 | | | 0.020 | 1300 | 3 |
| Average | 807 | 288 | 49445 | | Total Annual Copper From Campbell (kg) | 222 |

| | |
|---|---|
| Total Annual Copper From Ship Yards (kg) | 1,418 |

## APPENDIX B
## COPPER LOADING TO SAN DIEGO BAY
## ESTIMATES OF ANNUAL DISCHARGES OF COPPER FROM SHIP AND BOAT YARDS

| Station Number | 1993-94 Result (mg/kg) | Ship Yard Storm Drain Backgrounds (mg/kg) | Total Estimated Area of Commercial Basin (sq m) | Sample Thickness (m) | Dry Weight Sediment Density (kg/cu m) | Number of Years Represented by Sample |
|---|---|---|---|---|---|---|
| 93141 | 306 | 23.0 | | | | |
| 93141 | 299 | 190.0 | | | | |
| 93141 | 298 | 3.1 | | | | |
| 93141 | 284 | 288.0 | | | | |
| Average | 297 | 126 | 364000 | 0.020 | 1300 | 3 |

| | |
|---|---|
| Total Annual Copper From Commercial Basin Boat Yards (kg) | 539 |
| Total Annual Copper From Boat Yards (kg) | 674 |
| Total Annual Copper From Ship and Boat Yards (kg) | 2,092 |